CULTURABLE BACTERIAL ENDOPHYTES FROM BERMUDAGRASS AND TAQMAN® REAL-TIME PCR TO QUANTIFY *OPHIOSPHAERELLA HERPOTRICHA*

By

JANICE LYNN HIRONAKA

Bachelor of Science in Biological Sciences
California State University, Sacramento
Sacramento, California
1995

Master of Science in Botany
Oklahoma State University
Stillwater, Oklahoma
2000

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 2005

CULTURABLE BACTERIAL ENDOPHYTES FROM BERMUDAGRASS AND TAQMAN® REAL-TIME PCR TO QUANTIFY *OPHIOSPHAERELLA HERPOTRICHA*

Dissertation Approved:

Michael P. Anderson

Dissertation Adviser

Jacqueline A. Fletcher

Larry L. Singleton

Charles M. Taliaferro

A. Gordon Emslie

Dean of the Graduate College

ACKNOWLEDGEMENTS

I thank my major advisor, Michael P. Anderson, and my committee members, Jacqueline A. Fletcher, Larry L. Singleton, and Charles M. Taliaferro for their guidance and assistance.

I thank the Environmental Institute of Oklahoma State University for one year of financial support and the Department of Plant and Soil Sciences for one semester of financial support.

I thank Deborah S. Grove Ph. D., Director of Research Projects, Huck Institutes of the Life Sciences, The Pennsylvania State University, University Park, PA, for her assistance with the quantitative real-time PCR with TaqMan® chemistry protocol.

I thank my family, Jim M. and Elaine H. Hironaka, Laura Jane Hironaka, Paul Steven and Celine Hironaka, Erika Lynn Andriano, and Stephen Albert Andriano-Moore. I thank my nieces and nephew Sarah Jayne Hironaka, Sharolette Ray Hironaka, Sherreen Ann Leyden, Keegan M. Hironaka, and Kyley G. Hironaka for just being themselves. I also add to the list Sharolett's son, Jantzen Michael Cerrillo, and Sherreen's daughters, Josephine Jane Leyden and Zoey Rox-Ann Leyden, who have the world ahead of them. I also thank my extended family, my many Aunts, Uncles, and cousins. And a special thank you to Auntie Helen and Uncle Roy Wong.

I thank my wonderfully terrific husband, A. Daniel Jones, III, for his unwavering devotion, love, understanding, support, guidance, patience, and above all, smiles. I would not have finished my dissertation if not for you, sweetheart. You created a

supportive environment in which I was able to overcome years of migraines and finish my dissertation. I thank you with all that I am. I love you with all that I am.

PREFACE

Spring dead spot (SDS) is a devastating fungal disease of bermudagrass (*Cynodon dactylon* (L.) Pers. and *C. dactylon* X *C. transvaalensis* Burtt-Davy). The causal agents are *Ophiosphaerella korrae* (J. C. Walker & A. M. Smith) Shoemaker & C. E Babcock, *O. herpotricha* (Fr.:Fr.) Pers., and *O. narmari* Wetzel, Hulbert & Tisserat. These *Ophiosphaerella* spp. are soilborne, root-infecting fungi that live off of plant derived nutrients. Traditional pathogen control methods including the use of resistant bermudagrass cultivars, fungicides, and specific cultivation practices, have found limited success in controlling SDS in Oklahoma and Kansas. Biological control agents against SDS have yet to be developed. In hopes of finding culturable bacterial endophytes for development into biological control agents for SDS, bacterial endophytes were isolated from the crown tissue and rhizomes of SDS resistant Midlawn and susceptible Tifgreen bermudagrass cultivars, including SDS infected and non-infected plants. Endophytic bacteria were putatively identified to genera by sequencing contigs of their 16S rDNA and BLAST matching these sequences to the NCBI database. This is the first report, to the best of my knowledge, of a *Geodermatophilus* sp. and an *Amycolatopsis* sp. as plant endophytes and the first observation of a *Chryseobacterium* sp. with *in vitro* antifungal attributes. In addition, a real-time PCR assay with TaqMan® chemistry was developed to detect absolute quantities *O. herpotricha* DNA in plant and soil samples from 8 SDS infected cultivars varying in resistance to SDS.

TABLE OF CONTENTS

Chapter Page

I. REVIEW OF LITERATURE

Introduction....1
Description of Bermudagrass....3
Uses and Occurrences of Bermudagrass....8
Pests and Diseases of Bermudagrass....9
The Fungal Genus *Ophiosphaerella* Spegazzini 1909....11
Symptoms and Occurrence of Spring Dead Spot....12
Options for Control of Spring Dead Spot Disease....14
Endophytic Bacteria....18
Bacterial Endophytes as Biological Control Agents....24
Molecular Characterization of Bacteria in Plants and Soils....30
Techniques for Quantifying Fungi in Soils and Plant Tissues....32
Research Objectives....35
Bibliography....37

II. CULTURABLE BACTERIAL ENDOPHYTES FROM SPRING DEAD SPOT RESISTANT AND SUSCEPTIBLE BERMUDAGRASS CULTIVARS AND THEIR ANTIFUNGAL PROPERTIES

Abstract....46
Introduction....47
Material and Methods....53
Plant Materials....53
Surface Sterilization....54
Sterility Control Plates....55
Isolation of Culturable Endophytic Bacteria....56
Extraction of DNA from Bacterial Colonies....57
PCR Amplification, PCR Product Cleanup, and 16S rDNA Sequencing....58
DNA Sequence Analysis....59
Endophyte Putative Identification....60
Alignment of 16S rDNA Contig Sequence using ClustalX 1.8....60
De-Replication of *Microbacterium*....60
Cladogram of 128 Endophytic Bacterial Isolates....61
Selection of Type Species....62
Alignment of the 16S rDNA Contig Sequences....63
O. herpotricha Antagonism Assay....63

Chapter Page

Results....64
Discussion....68
Culturable Bacterial Endophytes....69
Abundance of Culturable Bacterial Colonies....70
Community Ecology of Culturable Bacterial Endophytes....70
Comparison of Resistant and Susceptible Cultivars....72
Endophyte Diversity in Healthy and Diseased Plants....73
In vitro Antagonism of Endophytes Towards *O. herpotricha*....73
Bacterial Endophytes as Biological Control Agents....76
Conclusions....76
Bibliography....93

III. DEVELOPMENT AND APPLICATION OF REAL-TIME PCR ASSAY FOR *O. HERPOTRICHA* USING TAQMAN® CHEMISTRY

Abstract....100
Introduction....101
Materials and Methods....106
Sample Harvesting for Measuring Spatial Distribution of *O. herpotricha*....106
Sample Harvesting for 8 Cultivars of Bermudagrass....107
Total Plant DNA Isolation....107
Total Soil DNA Isolation....108
O. herpotricha Genomic DNA Isolation....108
O. herpotricha Primers and TaqMan® Probe....109
Real-Time PCR Master Mix and Real-Time PCR Cycle....110
Standard Curve for Real-Time PCR....110
Analyses of Real-Time PCR Data....111
Optimization of *O. herpotricha* Amplification in Plant and Soil Samples....111
Specificity of the *O. herpotricha* Primers and TaqMan® Probe Set....111
Statistical Analyses....112
Results....112
O. herpotricha Primers and TaqMan® Probe....112
Experimental Verification of Selectivity....113
Sensitivity and Dynamic Range of Real-Time PCR Assay....113
Optimization for Matrix Effects....114
Sample to Sample Variation....115
Use of Assay – 8 Cultivar Study....115
Spatial Distribution of *O. herpotricha* in Greg Norman-1....116
Spatial Distribution of *O. herpotricha* in Midlawn....117

Chapter Page

Discussion 118
Goals of This Study 118
Assay Selectivity 119
Limits of Detection and Dynamic Range for *O. herpotricha* Genomic DNA 120
Interference by Sample Matrix, Plant, and Soil Samples 121
Ease of Use 122
Assay Reproducibility 123
Spatial Distribution of the Pathogen in 8 Cultivars 123
Spatial Distribution of the Pathogen in Greg Norman-1 and Midlawn 124
Conclusions 126
Bibliography 139

IV. APPENDIX

Appendix 1 142
Appendix 2 143
Appendix 3 188
Appendix 4 194
Appendix 5 199
Appendix 6 201
Appendix 7 202
Appendix 8 203
Appendix 9 208
Appendix 10 214
Bibliography 221

LIST OF TABLES

Table Page

Table 1. Taxonomy of *Cynodon dactylon* (L.) Pers....3
Table 2. Genus *Cynodon* L. C. Richard....4
Table 3. Bermudagrass cultivars....4
Table 4. Common names of *C. dactylon*....6
Table 5. *C. dactylon* used for Diverse Medical Ailments....8
Table 6. Important Pests of Bermudagrass....9
Table 7. Taxonomy of *Ophiosphaerella*....13
Table 8. Spring Dead Spot Fungi and Documented Locations....14
Table 9. Cultivation Practices to Reduce Spring Dead Spot....15
Table 10. Fungicides Recommended Against Spring Dead Spot....16
Table 11. Commercial Biological Control Agents....17
Table 12. Bacterial Endophytes Isolated from an Assortment of Plants....20
Table 13. Bacterial Endophytes Antagonistic Towards Phytopathological Fungi....25
Table 14. Culturable Bacterial Endophytes Data....78
Table 15. Number of Culturable Bacterial Endophytes....79
Table 16. Rules for Selecting the BLAST Identification....80
Table 17. Putative Identification of Culturable Bacterial Endophytes....81
Table 18. CFUs and Distribution of Culturable Bacterial Endophytes....83
Table 19. Culturable Endophytic Bacteria *in vitro* Antagonism....84
Table 20. CFUs of Putatively Identified Culturable Bacterial Endophytes....85
Table 21. Culturable Bacterial Endophytes Documented in Other Studies....86
Table 22. Nucleotide Sequences of the ITS Region....127
Table 23. Mean Threshold Cycle Values....128
Table 24. *O. herpotricha* DNA Concentrations in 8 Cultivars....129
Table 25. *O. herpotricha* DNA Concentrations in Midlawn Samples....130
Table 26. *O. herpotricha* DNA Concentrations in Greg Norman-1 Samples....131

LIST OF FIGURES

Figure Page

Figure 1. Neighbor-Joining Bootstrapped (1000X) Cladogram 87
Figure 2. The "*Gammaproteobacteria*" I and "*Alphaproteobacteria*" Clades 88
Figure 3. The "*Gammaproteobacteria*" II and "*Betaproteobacteria*" Clades 89
Figure 4. The "*Flavobacteria*", "*Bacilli*", and "*Actinobacteria*" I, II, III Clades 90
Figure 5. The "*Actinobacteria*" IV Clade 91
Figure 6. Cladogram composed of Endophytes and Type Species 92
Figure 7. Location of Plugs from Greg Norman-1 Plot A 132
Figure 8. Location of Plugs from Greg Norman-1 Plot B 133
Figure 9. Location of Plugs from Greg Norman-1 Plot C 134
Figure 10. Location of Plugs from Midlawn Plot A 135
Figure 11. Location of Plugs from Midlawn Plot B 136
Figure 12. Location of Plugs from Midlawn Plot C 137
Figure 13. Standard Curve of *O. herpotricha* genomic DNA 138

REVIEW OF LITERATURE

INTRODUCTION

Microbial phytopathogens cause great damage to agricultural crops and threaten the world's supply of food, timber, and natural fiber products. Despite pathogen control methods, fungal diseases still cause billions of dollars worth of economic losses to agriculture each year. As a consequence of globalization, introductions of non-endemic organisms pathogenic to crops and native plants present challenges to disease control efforts. New solutions are needed for effective and environmentally-friendly control of plant diseases.

Efforts to control diseases in turfgrasses and agricultural crops face many challenges. Fungal plant pathogens are sometimes non-responsive to fungicides due to resistance. Furthermore, resistance in plants can be overcome by evolving or non-endemic plant pathogens. Details regarding the nature of plant-pathogen interactions have not been fully elucidated in all cases, nor has the role of non-pathogenic microbes in plant disease or disease resistance been elucidated.

Recent scientific breakthroughs have made it easier to study plant-pathogen interactions and to identify and measure abundances of pathogenic and non-pathogenic microbes. DNA technologies have allowed scientists to quantify gene expression, leading to a better understanding of plant responses to pathogens. Accumulation of DNA

sequences into public databases accelerate these discoveries. These modern techniques are now being applied to study turfgrass diseases.

Bermudagrass is an economically important turfgrass. Bermudagrass is used in recreational areas, athletic fields, and as a forage grass in the sunbelt of America and in Australia, New Zealand, Africa, and tropical and subtropical regions of the world. In fact, the cultivar Greg Norman-1 turf was the playing surface for American football's Super Bowl XXXIII in Miami and American baseball's 1999 World Series in Atlanta. Unfortunately, this bermudagrass cultivar is quite susceptible to a fungal pathogen that causes a disease known as spring dead spot (SDS).

The most devastating fungal pathogens of bermudagrass are the three *Ophiosphaerella* Spegazzini 1909 spp., *O. korrae* (J. C. Walker & A. M. Smith) Shoemaker & C. E. Babcock, *O. herpotricha* (Fr.:Fr.) J. C. Walker, and *O. narmari* Wetzel, Hulbert & Tisserat, all of which can cause SDS. Better control of SDS requires correct identification of the SDS pathogens, development of resistant bermudagrass cultivars, specific cultural practices and more consistent fungicide treatments when SDS outbreaks are observed. Major advances have been made in pathogen detection by Tisserat at Colorado State University and coworkers at Kansas State University and Martin and coworkers at Oklahoma State University (Tisserat et al. 1994; Wetzel III et al. 1996; Wetzel III et al. 1999a; Wetzel III et al. 1999b; Tisserat et al. 2004). Development of cultivars with improved disease resistance has been led by Taliaferro and coworkers at Oklahoma State University. Better understanding of the interactions of bermudagrass with pathogenic and non-pathogenic microbes should lead to improved control methods.

Description of Bermudagrass

Bermudagrass (*Cynodon* L. C. Richard) is a vigorous warm season perennial sod-forming turf and forage grass. Bermudagrass grows rapidly during optimal growth conditions, forming a lush, thick mat that is highly resistant to wear and recuperates rapidly from turf injuries (vehicle tire ruts, golf divots, wash-outs). *Cynodon* L. C. Richard belongs to the Family *Poaceae* and the Tribe *Cynodonteae* (Table 1). The genus *Cynodon* includes nine species, ten varieties, and numerous cultivars (Tables 2 and 3). The species *C. dactylon* (L.) Pers. was initially described by Carl von Linnaeus followed by Christiaan Hendrik Persoon (1761-1836) (Brummitt and Powell 1992). *C. dactylon* is native to India and eastern Africa (Braun 1967; Correll and Johnston 1970; Beard 1973; Duble 1996) and has a plethora of common names (Table 4). Bermudagrass was introduced into the United States of America (US) from India or Africa in the late 1700s and was considered one of the major grasses in the southern states by 1807 (Duble 1996; Deputy et al. 1998).

Table 1. The taxonomy of *C. dactylon* (L.) Pers. (Anonymous 1997a).

Kingdom *Plantae*
Division *Magnoliophyta*
Class *Angiospermae*
Subclass *Commelinidae*
Order *Cyperales*
Family *Poaceae* Barnhart
Tribe *Cynodonteae*
Genus *Cynodon* L. C. Richard
Species *Cynodon dactylon* (L.) Pers.

Table 2. The genus *Cynodon* L. C. Richard, (after de Wet and Harland 1970 and Harland et al. 1970 as cataloged by Taliaferro (Taliaferro 1995)).

Epithet	Distribution
C. aethiopicus Clayton et Harlan	East African rift valleys
C. arculatus J. S. Presl. ex C. B. Presl.	Malagasy, southern India to northern Australia
C. barberi Rang. et Tad.	Southern India
C. dactylon (L.) Pers.	
var. *dactylon*	Cosmopolitan
var. *afghanicus* Harlan et de Wet	Afghanistan steeps
var. *aridus* Harlan et de Wet	Southern Africa northward to Palestine; east to South India
var. *coursii* (A. Camus) Harlan et de Wet	Madagascar
var. *elegans* Rendle	Southern Africa, south of lat. 13 ºS
var. *polevansii* (Stent)	Near Barberspan, South Africa
C. incompletus Nees	
var. *incompletus*	South Africa; Transvaal to Cape
var. *hirsutus* (Stent) de Wet et Harlan	South Africa; Transvaal to Cape
C. nlemfuensis Vanderyst	
var. *nlemfuensis*	East Africa
var. *robustus* Clayton et Harlan	East Tropical Africa
C. plectostachyus (K. Schum.) Pilger	East Tropical Africa
C. transvaalensis Burtt-Davy	South Africa
C. x *magennisii* Hurcombe	South Africa

Table 3. A list of bermudagrass cultivars released in the past 50 years. (Hanson 1972; Adams and Gibbs 1994; Alderson and Sharp 1994; Duble 1996; Deputy et al. 1998; Busey and Dudeck 2005).

Name	Year Released	Developed by, Recommended Uses
Coastal (Reg. No.1)	1943	Georgia Coastal Plain Experimental Station and Plant Science Research Division, ARS grazing and hay
U-3	1947	Released by ARS-USDA
Tiflawn	1952	Georgia AES
Midland (Reg. No. 2)	1953	Oklahoma AES, Georgia Costal Plain Experimental Station, Plant Science Research Division, AES, pasture
Suwannee (Reg. No.6)	1953	Georgia Costal Plain Experiment Station, Plant Science Research Division, ARS, grazing and hay
Tiffine	1953	Georgia AES, golf fairways, tees, before Tifgreen
Greenfield	1954	Oklahoma AES, pasture
Tifgreen	1956	Georgia AES, golf greens, fairways, tees

Name	Year Released	Developed by, Recommended Uses
Tiflawn (Reg. No. 4)	1956	Georgia Coastal Plain Experimental Station, Plant Science Research Division, AES, turf
Sunturf	1956	Alabama ASE
NK-37	1957	Northrup, King & Co.
Texturf	1957	Texas AES
Texturf 10	1957	Texas AES
Bayshore	1960	Florida AES
Royal Cape	1960	University of CA, Los Angeles, Plant Science Research Division, ARS., adapted to high salt areas of southern CA, turf
Tifway	1960	Georgia AES, golf courses, racetracks, lawns
Everglades	1962	Florida AES, putting green turf
Ormond	1962	Florida AES, golf tees and fairways
Tufcote	1962	SCS, National Plant Materials Center, Beltsville, MD, Maryland AES, heavy traffic areas, lawns, golf courses
Midway	1965	Kansas AES, turf
Tifdwarf	1965	Georgia AES, golf greens, superior putting quality, believed a vegetative mutant of Tifgreen
Santa Ana	1966	California AES, fine turf
Coastcross-1	1967	Georgia Costal Plain Experimental Station and Plant Science Research Division, ARS grazing and hay
Pee Dee 102	1968	South Georgia AES, golf greens in the southeastern US, a vegetative mutant of Tifgreen
Midiron	1971	Kansas AES, turf
Hardie (Reg. No. 11)	1974	Oklahoma AES, pasture and hay production
McCaleb	1975	University of Florida Institute of Food and Agricultural Science, Agricultural Research and Educational Center, Ona, FL, perennial forage grass
Tifton 44 (Reg. No. 10)	1978	Georgia AES and Fr-SEA-USDA, grazing and hay
Ona	1979	University of Florida Institute of Food and Agricultural Science, Agricultural Research and Educational Center, Ona, FL, perennial pasture grass
Tifway II (Reg. No. 15)	1981	ARS, Georgia Coastal Plain Experimental Station, U. S. Golf Association Greens Section, U. S. Department of Energy, turf
Brazos	1982	Texas AES, ARS and Louisiana AES, pasture, hay
Guymon	1982	Oklahoma AES, general purpose
Tifton 68 (Reg. No. 14)	1984	ARS and Georgia AES, grazing and hay
Tifton 78 (Reg. No. 17)	1984	University of GA and ARS, grazing and hay
Vamont	1986	Virginia AES
NuMex Sahara	1987	New Mexico AES, general purpose turf

Name	Year Released	Developed by, Recommended Uses
C2	1988	D. Palmer Seed Co., Inc., turf in very alkaline soils
Florico	1988	University of Florida Institute of Food and Agricultural Science, Agricultural research and Educational Center, Ona, FL, USDA-ARS, TARS (Puerto Rico), perennial pasture grass
Florona	1988	University of Florida Institute of Food and Agricultural Science, Agricultural research and Educational Center, Ona, FL, perennial pasture grass
Tifton 10	1988	Georgia Coastal Plain AES and ARS, turf
Cheyenne	1989	Jacklin Seed Co. and Pennington Seed, turf and reclamation
Primavera	1989	Farmers Marketing Corp., general purpose turf
Midfield	1991	Kansas and Oklahoma AES, transition zone turf
Midlawn	1991	Kansas and Oklahoma AES, transition zone turf
Tifton 85	1991	USDA-ARS, coastal Plain Experimental Station, grazing and hay
Sonesta	1992	O. M. Scott & Sons Co., general purpose turf for golf courses
Sundevil	1992	Jacklin Seed Co., turf and reclamation
Quickstand	1993	Kentucky AES, heavy recreational use
GN-1	1995	Greg Norman Turf
Yukon	1996	Oklahoma ASE
MS-Choice	1996	Mississippi AES, lawns, sports fields, more shade tolerant
MS-Express	1996	Mississippi AES, golf putting greens, tennis greens
MS-Pride	1996	Mississippi AES, lawns, golf tees and fairways

Table 4. Common names of *C. dactylon*. The list is not all inclusive (Dastur 1950; Watt and Breyer-Brandwijk 1962; Ayensu 1981; Jayaweera 1981; Boulos 1983; Duke and Ayensu 1985; Oudhia 2001; Wu 2002).

Language	Name
Arabic	endjil, nigil, moddad, medjem, madjir, zabak, kexmir, tsil, raifa
Bengali	durba
Berber	tizmit, affer, agesmir, tagamait, imelzi, haffar, toungane, agouzinir
Chinese	tie xian cao (iron weed grass), gai ya gen (dog teeth), pa ti cao (crawling grass), ai shen cao (dwarf grass), bai mo da (bermudagrass)
French	gros chiendent, herbe du bermudes, chiendent pied de poule, chiendent d'Italic, dactyle, petit chiendent
Hindi	dhoboghas, dubra, durba, dub, huriyale, kabbar, kalighas, khabbal
Kanarese	garikihallu
Marathi	durva

Language	Name
Punjab	dhubkhabbal
Sanskrit	amari, bahuvirya, durmara, gauri, haritali, jaya, mahaushadhi, nahavari, niladurva, rhha, shasravirya, shadvala, shanbhavi, shaspha, shataparva, shitakumbhi, tiktapara, vamini, vijaya
Sotho	mohloa, mohlwa, hoholoa, morara, seihla
Tamil	arugampillu, hariali
Telug	garikagoddi
Tswana	mothowa, motwa
Xhosa	uqaqaqa
Zulu	isifulwane, ungwengwe, umqambalala, umqambalalane, uqethu

Additional common names are: Australian couch grass, Bahama grass, batawiesek week, Bermuda grass, Bermuakweekgras, Bermuda quick grass, Buffel grass, couch grass, creeping cynodon, creeping panic grass, devil's grass, dog tooth, elandskweek, fine couch grass, fine qauick, fingers, Florida grass, fynkweekgras, gariesgras, germiston grass, hardekweek, Indian couch grass, Indiesekweek, kruisgras, kwaggakweek, kweekgras, lawn grass, oostindiesekweekgras, quagga quick, quick grass, regteweekgras, riverkweek, running grass, Scotch grass, scucch grass, star grass, vingergras, white quick grass, and wire grass.

Bermudagrass reproduces vegetatively from underground rhizomes and above ground stolons, and sexually by seed. Providing nutrients are not limiting, the grass is highly adapted to soils ranging from heavy clays to deep sands, acid, alkaline, and saline conditions. On the negative side, bermudagrass cannot withstand low temperatures, long periods of freezing, or even partial shade (Gould 1973; Turgeon 1991; Duble 1996).

The cultivars of bermudagrass include both natural and man-made hybrids. Bermudagrass cultivars, or 'improved' bermudagrasses, are found throughout the tropical and subtropical areas of the world. Improved bermudagrasses are heat and drought tolerant, moderately cold tolerant, and require high soil fertility for a healthy turf. Cultivars have been developed and released by Agricultural Experiment Stations (AES) of several US land grant institutions, the Crops Research Division-Agricultural Research Service-United States Division of Agriculture (ARS-USDA), Sod Growers Associations,

and other private interests (Adams and Gibbs 1994; Duble 1996; Deputy et al. 1998) (Table 3) for a variety of uses.

Uses and Occurrences of Bermudagrass

Bermudagrass is widely used as a turfgrass predominately for golf courses, polo fields, athletic playing fields, parks, other recreational areas, residential housing units, and roadside erosion and dust control (Duble 1996). In Oklahoma, bermudagrass turf is extensively used and the estimated replacement cost is approximately $1.7 billion dollars.

Versatile bermudagrass is not only used for turf, forage, and pasture grass, but is an important component in ceremonies and an ingredient in folk remedies. Bermudagrass is used in religious festivals in India and as an ingredient in herbal cures for diarrhea, scalp dryness, and headaches (Table 5).

Table 5. *Cynodon dactylon* is used for diverse medical ailments by many cultures (Dastur 1950; Watt and Breyer-Brandwijk 1962; Ayensu 1981; Cribb and Cribb 1981; Jayaweera 1981; Boulos 1983; Duke and Ayensu 1985).

Arrest bleeding	Ceylon, China, India, Pakistan, North Africa
Diuretic	Australia, Ceylon, China, India, North Africa, Pakistan, Philippines, West Indies
Dysentery	Ceylon, India, Pakistan
Epilepsy	Ceylon
Hysteria	Ceylon, India, Pakistan
Insanity	Ceylon, India, Pakistan
Inflammation of a body opening	Ceylon, India, Pakistan
Secondary syphilis	Ceylon, India, Pakistan
Gout	Australia, Madagascar, India, Pakistan
Rheumatic affections	Australia, Madagascar, India, Pakistan
Blood purifier	Africa, China, North Africa
Laxative	China
Urinary bladder inflammation	Australia, India, North Africa, Pakistan, West Indies

The exact qualities that make bermudagrass an excellent forage and turfgrass also make bermudagrass as an aggressive and invasive weed. The State of California has acknowledged the importance of bermudagrass as a weeds (*Cynodon* spp. and hybrids) and has placed them on the 'noxious weeds' list (California Department of Food and Agriculture 2005). A 'noxious weed' is "troublesome, aggressive, intrusive, detrimental, or destructive to agriculture, silviculture, or important native species, and difficult to control or eradicate" (California Department of Food and Agriculture 2005). Bermudagrass as a weed is an unwelcome visitor that usually requires much work to eradicate.

Pests and Diseases of Bermudagrass

Bermudagrass, though a versatile and extensively planted turfgrass, is vulnerable to a number of pests. Lucas and Bruneau (1995) wrote concerning bermudagrass, "Many pest problems . . . [diseases, weeds, insects, and animals] cause your turf to look bad ... If you are really unlucky, you may have all of them at one time." Taliaferro (1995) listed 15 insects, 8 nematodes, and 17 fungi that are important pests of *Cynodon* spp. A list of these is described in Table 6.

Table 6. Important pests of bermudagrass including insects, bacteria, fungi and one miscellaneous pest. (Rogerson 1958; Shurtleff et al. 1987; Smiley et al. 1992; Sauer et al. 1993; Vargas 1994; Taliaferro 1995; Fermanian et al. 2003; Taliaferro et al. 2004).

Insects
Armyworm, *Spodoptera frugiperda* J. E. Smith
Bermudagrass mites, *Eriophyes cynodoniensis*
Bermudagrass scales, *Odonaspisruthae* spp.
Chinch bugs, *Bilssus leucopterus*
Grasshoppers, *Melanoplus* spp.
Ground pearls, *Margarodes* spp.
Phoenix billbug, *Sphenophorus phoeniciensis*

Insects
Pyrilid grassworm, *Marasmia trapezalis* Guenée
Spittlebugs, *Prosapia bicincta* Say.
Sod webworm, *Fissicrambus haytiellus* Zinck.
Striped grass looper, *Mocis latipes* Guenée
Tawny mole cricket, *Scaptericus vicinus* Scudder
White grubs, *Phyllopaga* spp.

Nematodes
Awl, *Polichodorus* spp.
Burrowing, *Radopholus* spp.
Dagger, *Xiphinema* spp.
Lance, *Hoplolaimus* spp.
Lesion, *Pratylenchus* spp.
Needle, *Longidorus* spp.
Pin, *Paratylenchus* spp.
Root knot, *Meloidogyne* spp.
Spiral, *Helicotylenchus* spp.
Sting, *Belonolaimus* spp.

Bacteria
Bacteria wilt, *Xanthomonas campestris* pv. *graminis*

Fungi
Anthracnose, *Colletotrichum graminicola* (Ces.) Wils.
Bermudagrass decline, *Gaeumannomyces graminis* (Sacc.)Arx & Oliver var. *graminis*
Brown patch, *Rhizoctonia* spp.
Brown stripe, *Cercosporidium graminis* (Fuckel) Deighton
Cercospora leaf spot, *Cercospora seminalis*
Copper spot, *Gloeocercospora sorghi* Bain & Edgerton ex. Deighton
Dollar spot, *Sclerotinia homoeocarpa* F. T. Bennett
Gray leaf spot, *Pyricularia grisea* (Cooke) Sacc.
Leaf blotch, crown, and root rot, *Bipolaris cynodontis* (Marig.)Shoemaker
Leaf blotch, *Drechslera cynodontis* Nelson, *Helminthosporium giganteum* Heald & Wolf, *H. rostratum* Dreschsl., *H. spiciferum* (Bain.) Nicot, *H. stenospilum* Dreschsl., *H. triseptatum* Dreschsl.
Leaf spot, *Exserohilum rostratum*
Leaf spot, leaf, crown, root rot, *B. sorokiniana*
Physoderma leaf spot, leaf streak, *Physoderma graminis*
Pink patch, *Limonomyces roseipellis* Stalpers & Loerkker
Powdery mildew, *Erysipha graminis* DC.
Pythium blight, grease spot, cottony blight, *Pythium aphanidermatum* (Edson) Fitspatrick, *P. ultimum* Trow
Red thread, *Laetisaria fucifornis* (McAlp.) Burdsell
Rust, *Puccinia cynodontis* Lac. ex Desmaz
Spring dead spot (SDS), *Ophiosphaerella herpotricha, O. korrae O. narmari*

Fungi
Southern, Sclerotium blight, *Sclerotium rolfsii*
Stem, crown, and root necrosis, *B. spicifera*
Yellow leaf spot, *Drechslera tritici-repentis*
Yellow patch, Rhizoctonia yellow patch, *Rhizoctonia cerealis*
Zonate leaf spot, *D. gigantea*

Miscellaneous
Slime mold, *Physarum cinereum* (Batsch.) Pers.

Spring dead spot (SDS), caused by three *Ophiosphaerella* spp., is the single most destructive disease of bermudagrass (Tisserat et al. 1989, Duble 1996; Watschke et al. 1995; Wetzel III et al. 1999a) and is pathogenic to other grasses as well. The genus *Ophiosphaerella* was described by Spegazzini in 1909 and belongs to the Class *Ascomycetes* and the Order *Pleosporales* (Table 7). *O. korrae* causes necrotic ring spot in Kentucky (*Poa pratensis* L.) and annual bluegrasses (*P. annua*) and creeping red fescue (*Festuca rubra* var. *rubra*) (McCarty and Lucas 1989; Dernoeden 1999). Although the primary host of *O. herpotricha* is bermudagrass, *O. herpotricha* causes a patch disease in zoysiagrass (*Zoysia japonica* Steud.) and SDS in buffalograss (*Buchloe dactyloides*) (Green II et al. 1993; Dernoeden 1999).

The Fungal Genus *Ophiosphaerella* Spegazzini 1909

The taxonomy of *Ophiosphaerella* spp. has changed over the years, making older literature somewhat confusing. *Ophiosphaerella korrae* was first described in 1965 as *Ophiobolus herpotrichus* (Fr.) Sacc., redescribed in 1972 as *Leptosphaeria korrae* J. C. Walker & A. M. Smith, and finally renamed in 1989 as *Ophiosphaerella korrae*. *Ophiosphaerella narmari* was first described in 1972 as *Leptosphaeria narmari* J. C. Walker & A. M. Smith, then, in 1989 was reclassified as *Phaeosphaeria narmari* (J. C.

Walker & A. M. Smith) Shoemaker & C. E. Babcock, and, in 1999, redescribed as *Ophiosphaerella narmari* (Wetzel III et al. 1999a). In 1989, Tisserat et al. concluded *Ophiosphaerella herpotricha* (Fr.) Walker was a synonym for *Ophiobolus herpotrichus*. Landschoot (1993) assigned the following synonyms to *Ophiosphaerella herpotricha*, *Ophiobolus herpotrichus* (Fr.:Fr.) Sacc. & Roum., *Phaeosphaeria herpotricha* (Fr.:Fr.) L. Holm, *Ophiobolus medusae* Ellis & Everh. f. *brimi* Brenckle*, Ophiobolus oryzae* Miyabe, and *Scolecosporiella* sp. (anamorph).

Symptoms and Occurrence of Spring Dead Spot Disease

In the United States, SDS infects bermudagrass in locations where the plant goes into dormancy in the winter. The geographic zone of SDS is the at the northern range of bermudagrass adaptation (Tisserat 1989) where average temperatures in the late autumn are between 7.2 to 13.9 °C. The longer cold temperatures persist, the greater the disease (Fermanian et al. 2003).

The habit of SDS fungal pathogens is soilborne, ectotrophic (coating the exterior surface), and root-infecting (sending hyphae into the root) (Smiley and Fowler 1984). Optimum soil temperatures of 15 – 25 °C induce *O. herpotricha* colonization (Fermanian et al. 2003). The progression of the disease is slow, usually taking about 2 to 3 years to establish. The fungi first colonize the outer surfaces of underground structures forming an epiphytic dark coating of hyphae followed by hyphal penetration into the cortex to extract nutrients. SDS is most evident in three to six year old intensely managed bermudagrass turf. The disease becomes obvious when the grass breaks dormancy in the spring. Round, bleached areas, from three to one meter in diameter, indicate where SDS has killed the turf.

Table 7. The taxonomy of the genera *Ophiosphaerella* (Landschoot 1993).

Kingdom *Fungi*
Division *Ascomycota*
Subdivision *Ascomycotina*
Class *Ascomycetes*
Subclass *Loculoascomycetidae (Loculoascomycetes)*
Order *Pleosporales* Luttrell ex Barr 1983
Family *Phaeosphaeriaceae* M. E. Berg 1979
Genus *Ophiosphaerella* Spegazzini 1909
Species *Ophiosphaerella herpotricha* (Fr.:Fr.) J. C. Walker
Species *Ophiosphaerella korrae* (J. C. Walker & A. M. Smith) Shoemaker & C. E. Babcock
Species *Ophiosphaerella narmari* Wetzel, Hulbert & Tisserat, comb. nov.

The recent history of SDS spans two continents. Symptoms similar to SDS have been observed sporadically in Oklahoma since 1936, and in 1960 the term spring dead spot was coined by Wadsworth and Young. SDS was first documented in Australia in 1965, and shortly thereafter in New Zealand. SDS was first reported in North Carolina in the late 1960s (Smiley 1993) and first documented in southern California in 1983 (Endo et al. 1985). During these years, identifications of causal agents were tentative, incorrect, or unknown because they relied on symptoms or fungal morphological assessments that often gave ambiguous conclusions. With the advent of molecular techniques, identification of *Ophiosphaerella* spp. can now be made with certainty (O'Gorman et al. 1994; Tisserat et al. 1994; Wetzel III et al. 1999a; Wetzel III et al. 1999b).

Identification of the pathogen in a host is of the utmost importance for successful disease control. Tisserat et al. (1994) developed species-specific DNA probes derived from internal transcribed spacer (ITS) regions from *O. korrae* and *O. herpotricha*. The

DNA probes were used to identify these fungi in artificial and naturally infected bermudagrass roots. The *O. herpotricha* DNA probe amplified DNA from *O. herpotricha* but not 30 other isolates, including *O. korrae*. The *O. korrae* DNA probe detected only *O. korrae* and not the other 30 isolates tested. Wetzel III et al. (1999a) were able to identify, for the first time, the presence of *O. narmari* Wetzel, Hulbert & Tisserat, comb nov. (=*Leptosphaeria narmari*) in North America using species-specific DNA probes. With these and other molecular and microbiological tools, identification of SDS pathogens has become more accurate. The markers assist researchers in defining their geographical range. SDS has been found to be widespread and caused by different species in different regions (Table 8).

Table 8. Spring dead spot fungi and documented locations (Endo et al. 1985; Tisserat et al. 1989; Jackson 1993; Venkatasubbaiah et al. 1994; Chastagner and Hammer 1997).

Species	Location
Ophiosphaerella herpotricha	Kansas, Kentucky, Louisiana, Missouri, North Carolina, Oklahoma, Texas
O. korrae	California, Colorado, Maryland, Michigan, New York, Utah, Washington, Australia
O. narmari	USA, Australia, New Zealand

Options for Control of Spring Dead Spot Disease

The most common approach to control of fungal diseases involves the use of chemical fungicides. Fungicide treatments recommended for use in Alabama, Kentucky, Maryland, and Texas were ineffective in controlling SDS in Kansas and Oklahoma (Anonymous 1999a; Vincelli 2000; Dernoeden 2000; Hagan 1997). Fungicide treatments discouraged for the control of SDS by the Oklahoma and Kansas Cooperative Extension

Services who recommended specific cultivation practices to contain and control SDS (Martin and Hudgins 1998; Tisserat 1998) (Table 9). Extensive cultivation practices are time consuming, expensive, and only partially effective, and need to be evaluated over several years. Furthermore, there are no truly resistant varieties of bermudagrass although efforts to develop these are in progress. Several of these control practices may be cost effective for home lawns or small turfgrass plots in other geographic areas but can be cost prohibitive for larger areas, such as: golf courses, parks, and athletic fields.

Table 9. Cultivation practices recommended by the Oklahoma, Kansas, and Alabama Cooperative Extension Services to reduce the impact of SDS on bermudagrass (Hagan 1997; Martin and Hudgins 1998; Vincelli and Powell 2000).

Removal of excess thatch
Maintenance of soil pH at 5.8 – 6.2
Light annual liming
Annual core aerification
Soil testing for potassium and phosphorus yearly and add if deficient
Use ammonium sulfate or ammonium chloride for nitrogen application, apply lightly but frequently through the growing season
Monthly micronutrient sprays
Use slow-release forms of organic or inorganic fertilizers
Autumn potash application
No N, P, and K applications after the first week in September

The use of fungicides is not only costly but potentially toxic to nontarget organisms, including fungicide applicators. Six fungicides are recommended to control SDS (Table 10) but these fungicides pose risks to ecosystems and human health. At low levels, fernarimol and thiophanate-methyl are toxic to fish (Anonymous 1998, 2000a, b) with the remaining four fungicides toxic to freshwater, estuarine, and marine fish and invertebrates (Anonymous 1999b, 2000c, d, e). Azoxystrobin, farnarimol, propiconazole,

and thiophanate methyl are toxic to the liver, while fernarimol shows reproductive and fertility effects, and of myclobutanil and thiophanate-methyl shows reproductive and embryoteratotoxicity (Anonymous 1997b, c, 1987, 1999b, 2000a-d). These fungicides can be transported out of treated areas toward nontarget areas by winds and water runoff, posing a threat to surrounding and distant ecosystems. Furthermore fungicides may lose their effectiveness over time if fungal pathogens develop resistance (Clarke et al. 1997). These ramifications demonstrate the need to develop effective and safer alternatives to control SDS.

Table 10. Fungicides recommended for use against spring dead spot.

Common Name	Trade Name
Azoxystrobin	Heritage, Abound
Chlorothalonil	Daconil, Bravo
Fenarimol	Rubigan
Myclobutanil	Eagle
Propiconazole	Banner Maxx, Tilt
Thiophanate-methyl	Fungo, 3336WP

(Hagan 1997; Martin 1999; Vincelli and Powell 2000; Anonymous 2001).

SDS remains a problem even when the most resistant bermudagrass cultivars and most prudent cultivation practices are used. Given the limited effectiveness of fungicide treatments, biological control agents hold promise as an more environmentally friendly and time saving alternative. A safe and cost-effective alternative to controlling plant diseases is through the use of antagonistic organisms in a process known as biological control. Natural bacteria, as opposed to transgenic bacteria, are perhaps the most promising agents for biological control of fungal diseases in plants. In agriculture,

biological control is a widely accepted strategy for controlling pests, and presents a reasonable and less expensive alternative to massive fungicide treatments or extensive cultivation practices (Table 11).

Table 11. A small sampling of commercial biological control agents against soilborne crop diseases (Hinton and Bacon 1995; Anonymous 2000f; Vasudevan et al. 2002; Ritter 2003).

Biological Control Organism	Target	Crop
Agrobacterium radiobacter	*Agrobacterium tumifaciens*	Trees
Bacillus laterosporus (V)	*Rhizoctonia solani*	Rice
Bacillus pumilus (V)	*Rhizoctonia solani*	Rice
	Sclerotium oryzae	Rice
Bacillus subtilis GB03	*Rhizoctonia*	Horticultural
	Pythium	Turfgrass
	Fusarium	
	Phytophthora	
Bacillus subtilis B2g (M)	*Pythium ultimum*	
	Rhizoctonia solani	
Bacillus subtilis QST-713 (r)	Fungi	Tomato, letuce, grapes
Burkholderia cepacia	*Pseudomonas cepacia*	Legumes
	Rhizoctonia	Wheat
	Phthium	Barley
	Fusarium	Cotton
		Grain Sorghum
		Vegetable corps
Enterobacter cloacae (H B)	Fungi	Fruits, vegetables
Pseudomonas aeruginosa (V)	*Drechslera oryzae*	Rice
Pseudomonas aureofaciens Tx-1	Dollar spot	Turfgrass
	Anthracnose	
	Pythium aphanidermatum	
	Michrochium patch (pink snow mold)	
Pseudomonas fluorescens A506	Frost damage	Almond
	Erwinia amylovora	Fruit trees
	Russet-inducing bacteria	Tomato
Pseudomonas fluorescens (V)	*Magnaporthe grisea*	Rice
Pseudomonas putida (V)	*Rhizoctonia solani*	Rice

Biological Control Organism	Target	Crop
Serratia marcescens (V)	*Rhizoctonia solani*	Rice
Stenotrophomonas maltophilia C3	*Bipolaris sorokiniana*	Turfgrass (Z)
Streptomyces griseoviridis K61	*Fusarium* spp.	Ornamental
	Pythium spp.	Vegetable crops
	Phytophthora spp.	

Endophytic Bacteria

Before 1876, bacteria were thought to appear by spontaneous generation. In spite of Pasteur and Koch's discovery in 1876 that mammalian anthrax was caused by a bacterium, and T. J. Burril's findings in 1878, that fire blight disease of pomes was also caused by a bacterium, scientists were skeptical until the 20th century that bacteria could be found in plants. Studies from 1876 to 1896 supported the hypothesis that healthy plants did not contain bacteria, and the subject was largely ignored from 1896 to 1948, when fewer than 25 scientific papers dealt with plants and bacteria (Hollis 1951). Interest re-emerged in the mid 1950s, when studies of the biology and ecology of bacteria in plant roots began. Philipson and Blair (1957), documenting the mixed bacterial flora of clover roots, isolated three groups of endophytic bacteria: *Aerobacter cloacae, Bacillus megatherium*, and *Flavobacterium rhenanus*.

The definition of the term endophyte (Greek, 'endon' within, 'phyte' plant) has undergone several modifications. The original definition of endophyte was used to describe fungi living inside plants without causing disease (Chanway 1996). Then the term endophyte was expanded to include parasites (biotrophic parasites to facultative saprotrophic), mutualists (biotrophic mutualists, benign commensals to nectotrophic), and antagonistic pathogens (Stone et al. 2000). Currently, and in this study, the definition of

endophyte includes only microorganisms that reside inside a plant, during part or all of their life cycle, without causing disease symptoms (Chanway 1996).

Microbial endophytes have a sustained intimate relationship with plants. They live in virtually all plant tissues (Table 12); some are benign, some enhance plant growth, and some impact disease severity. The endophyte-plant relationship may have begun when plants first evolved on earth. Some specimens of fossilized plant tissue show plant-microbe associations (Strobel 2003). During the past 50 years, a small fraction of the approximately 300,000 plant species on earth have been subjects for endophyte studies, and all of these plants, several hundred, host a complement of microbes (Strobel 2003). Bacterial endophytes are closely associated with the plant, and some also thrive in the rhizosphere. Seed endophytes are usually passed into the germinating plant and are thereby passed on from generation to generation through a process of vertical transmission. Some soil bacteria have the potential to either penetrate or enter the roots through wounds and travel into the shoot system.

Bacteria gain entry to plants through a variety of ways, including natural openings, such as hydathodes, lentices, micropores, and stomates; natural wounds, such as leaf and bud scale scars; and wounds caused by external forces, such as wind or pathogens. Roots may be the preferred site of entry for bacterial endophytes (Hallmann 2001). Bacteria enter the root from ruptures in the epidermis made by emerging roots, at the junction of a root hair and its epidermal cell, and between epidermal cells (Parke 1991). Hydrolytic enzymes that are capable of hydrolyzing the plant cell wall may be secreted by bacterial endophytes and may provide *the mechanisms* for endophytic entry into plant roots (Quadt-Hallmann et al. 1997; Kovtunovych et al. 1999).

Table 12. Bacterial endophytes isolated from an assortment of plants and plant organs. For a more exhaustive list, see Appendices 7, 8 and 10.

Endophyte	Plant	Tissue	Reference
Acetobacter	Pineapple	Plant tissues	(Tapia-Hernandez et al. 2000)
Acetobacter	Sugarcane	Stem	(Dong et al. 1994)
Acetobacterium	Sea Grass	Cortex	(Kusel et al. 1999)
Achromobacter	Citrus	Xylem	(Gardner et al. 1982)
Acidovorax	Clover	Roots	(Sturz et al. 1998)
Aerococcus	Cotton	Plant tissues	(Chen et al. 1995)
Agrobacterium	Carrot	Plant tissues	(Surette et al. 2003)
Agrobacterium	Healthy rose	Plant tissues	(Marti et al. 1999)
Arthrobacter	Canola	Root	(Germida et al. 1998)
Azoarcus	Grass	Plant tissues	(Hurek et al. 2002)
Azospirillum	Rice	Root	(Engelhard et al. 2000)
Bacillus	Aspen	Wood	(Knutson 1973)
Bacillus	Corn	Kernel	(Bacon and Hinton 2002)
Bacillus	Live oak	Plant tissues	(Brooks et al. 1994)
Bacillus	Wheat	Root	(Germida and Siciliano 2001)
Burkholderia	Banana	Plant tissues	(Pan et al. 1997)
Burkholderia	Rice	Root	(Englehard et al. 2000)
Clavibacter	Grapevine	Xylem	(Bell et al. 1995)
Clostridium carbonei	Pinto Beans	Plant tissues	(Thomas Jr. and Graham 1948)
Corynebacterium	Sugar beet	Root	(Jacobs et al. 1985)
Curtobacterium	Yam	Tuber	(Mantell 1998)
Enterobacter	Spinach	Root	(Tsuda et al. 2001)
Enterobacter	Lemon	Root	(Gardner et al. 1982)
Erwinia	Aspen tree	Wood	(Knutson 1973)
Gluconacetobacter	Sugarcane	Plant tissues	(Boddey et al. 2003)
Herbaspirillum	Rice	Root	(Englehard et al. 2000)
Methylobacterium	Scots pine	Plant tissues	(Mattila 2001)
Mycobacterium	Scots pine	Branch Bud	(Mattila 2001)
Nocardia	Citrus	Branch	(Araújo et al. 2002)
Pantoea	Potato	Tuber	(Sturz et al. 1999)
Proteus	27 plants	Ovule,seed	(Mundt and Hinkle 1976)
Pseudomonas	Alfalfa	Root	(Gagné et al. 1987)
Pseudomonas	Elm	Stem, root	(Mocali et al. 2003)
Pseudomonas	Live oak	Plant tissues	(Brooks et al. 1994)

Endophyte	Plant	Tissue	Reference
Pseudomonas	Sorghum	Stem	(Zinniel et al. 2002)
Stenotrophomonas	Elm	Stem, root	(Mocali et al. 2003)
Streptomyces	Laurel	Plant tissues	(Nishimura et al. 2002)
Microbacterium	Trufgrass	Seed, root	(Sundaram et al. 1988)
Xanthomonas	Mulberry	Shoot	(Sato et al. 2000)

Bacterial endophyte studies, since the early 1980s, concentrated mainly on documenting genera, ecological and population dynamics, growth-promoting endophytes, and antibiosis towards known pathogens. Bacterial endophyte studies have also included comparisons among different cultivars and between healthy and diseased plants.

Fundamental ecological studies of endophytic bacterial population dynamics in corn and cotton roots were conducted by McInroy and Kloepper (McInroy and Kloepper 1995), who found that corn stems and roots were colonized with endophytic bacteria at the time of seedling emergence in the field. The number of colony forming units (CFU) present in surface sterilized corn and cotton seeds planted in non-sterilized potting mix were three-fold higher in corn than cotton six days after planting. The seed endophytic bacterial population dynamics in cotton petioles and bolls were established one year after planting in the field.

The taxonomic diversity and abundance of endophytic bacteria may be influenced by plant cultivar. Sturz and Christie (1998), characterizing the culturable bacterial endophytes (Table 12) from the roots of four red clover (*Trifolium pratense* L.) cultivars found differences in species richness and abundance between cultivars. In contrast, Sturz et al. (1999) found no significant differences in species richness or abundance when he characterized culturable bacterial endophytes from the tubers of four cultivars of potato. In a related study, Adams and Kloepper (2002) characterized nine cotton (*Gossypium*

hirsutum L.) cultivars ranging in susceptibility to Fusarium wilt. Cultivar differences were found in the total endophytic bacterial population of four day old radicles. Microbial abundances did not correspond with the susceptibility of the cultivars. Germida and Siciliano (2001) documented a higher species diversity among culturable bacterial endophytes in the roots of recent cultivars of rice as compared to that in an ancient land race.

Bacterial endophytes not only colonize the cortex of roots and stems but can enter the stele and the xylem. When Gagne et al. (1987) investigated the populations in root and crown xylem tissue of healthy field-grown alfalfa plants, 6.0×10^3 to 4.3×10^4 colony forming units (CFUs) per g of fresh xylem sap, were measured. Age, cultivar, or sampling site did not affect endophytic bacterial populations. Gardner et al. (1982) studied the bacterial endophyte population in the xylem of Florida citrus trees. They vacuum extracted xylem fluid from healthy and young diseased trees (tree decline disease, no pathogen named). Their data suggest average bacterial counts from the years 1979 through 1981 were consistently higher in the diseased trees than in the healthy trees. They concluded xylem bacteria played an "important role in the physiology of citrus."

Disease agents in plants may influence the diversity and abundance of bacterial endophytes because of competition and antibiosis, which may either be increased or decreased depending upon the pathogen and bacterial endophytes. Araujo et al. (2002) found the branches of citrus trees infected with *Xylella fastidiosa*, the causal agent of citrus variegated chlorosis, had greater bacterial endophyte diversity than non-infected citrus plants. Also, potato plants infected with *Erwinia carotovora* subsp. *atroseptica* had a higher bacterial endophytic diversity than non-infected plants (Reiter et al. 2002).

Nitrogen fixing bacteria, previously thought to colonize only legumes, have been documented in non-legume plants. Baldani et al. (1986) characterized a previously undescribed nitrogen fixing root endophytic genus, *Herbaspirillum seropedicae* gen. nov., sp. nov. isolated from corn, sorghum, and rice. Barraquio et al. (1997) also isolated nitrogen fixing bacterial root endophytes from rice to investigate the colonization, persistence, nitrogen fixation, and unique combinations of endophytic nitrogen fixing bacteria. They noticed higher nitrogen fixing bacterial populations in roots during the grain ripening stage in field-grown IR72 rice plants without nitrogen fertilizer. Stoltzfus et al. (1997) wanted to increase the growth rate and yield of rice through naturally occurring endophytic nitrogen fixing bacteria isolated from rice roots, or an endophytic bacterium that could be genetically engineered to fix nitrogen. They were successful in isolating 24 nitrogen fixing bacterial species from rice roots. Along with the beneficial aspect of nitrogen fixing, some bacterial endophytes also displayed anti-pathogenic properties. These, and other discoveries, enticed more scientists to investigate endophytes in different plant genera.

The bacterial colonization of external lodgepole pine seedling roots and the influence upon the seedlings were studied by Shishido et al. (1995). Greenhouse grown pine seedlings assayed nine weeks after inoculation with the endophyte *Bacillus polymyxa* Pw-2 grew "significantly taller" with "significantly" more shoot and root biomass than non-inoculated seedlings. Bacterial endophytes have been documented in different root tissues and found to be, in some cases, not just benign but beneficial.

Bacterial endophytes have been and are currently investigated for antibiotic properties. In 1995, Hinton and Bacon found *Enterobacter cloaceae* to be antagonistic

against the corn pathogen *Fusarium moniliforme* and two other mycotoxin producing fungi. Adhikari et al. (2001) challenged *in vitro* the rice pathogenic fungi *Achyla klebsiana* and *Pythium spinosum* with 3 *Pseudomonas* spp. and *Sphingomonas trueperi* and showed that all inhibited fungal growth. Sturz et al. (1999) isolated 13 endophytic bacteria from potato tubers that were antagonistic against *Fusarium* spp. The grass bacterial endophyte *Stenotrophomonas maltophilia* strain C3, field tested on tall fescue cv. 'Kentucky 31', controlled *Rhizoctonia solani* Kuhn, the causal agent of brown patch disease, on one of six field plots (Giesler and Yuen 1998). *S. maltophilia* also inhibited *R. solani* and *Verticillium dahliae* var. *longisporum* (Berg et al. 1996).

Bacterial Endophytes as Biological Control Agents

There are numerous advantages in using endophytic bacteria as biological control agents. Some endophytic bacteria survive in the surrounding plant rhizosphere, readily enter and colonize the host (Kageyama et al. 1992; Pleban et al. 1995; Tsuda et al. 2001), and retain their effectiveness through storage (Fravel 2000; Ritter 2003). Some endophytic bacteria excrete chitinases and proteases, produce secondary metabolites with antibiotic properties, and induce resistance in plants (Table 13). Endophytic bacteria can be as effective as fungicides in controlling select fungal pathogens, minimizing environmental threats and negative impacts on human health.

Table 13. Bacterial endophytes with antagonism towards phytopathogenic fungi. For a more exhaustive list, see Appendix 10.

Bacterial Endophyte	Isolated From	Antagonism Property	Host Plant or *in vitro*	Pathogen	Reference
Agrobacterium tumefaciens	Potato tuber	Antagonism	*in vitro*	*Phytophthora infestans* A1, A2	(Sturz et al. 1999)
Bacillus cereus	*Sinapis*	Chitinase	*in vitro*	*Rhizoctonia solani*	(Pleban et al. 1995)
B. licheniformis	Oilseed rape	Protease	*in vitro*	*Verticillium longisporum*	(Graner et al. 2003)
B. mojavensis	Corn kernel	Antagonism	*in vitro*	*Fusarium moniliforme*	(Bacon and Hinton 2002)
B. pumilus	Endophyte	Induced defense-related ultrastructural modifications	Pea	*Fusarium oxysporum* f. sp. *pisi*	(Benhamou et al. 1996)
Burkholderia (Pseudomonas) cepacia	Asparagus	Mycelia deformation	Banana	*Fusarium oxysporum* f. sp. *cubense* race 4	(Pan et al. 1997)
Cytophaga johnsonae	Oilseed rape	Protease	*in vitro*	*Verticillium longisporum*	(Graner et al. 2003)
Paenibacillus polymyxa	Oilseed rape	Protease	*in vitro*	*Verticillium longisporum*	(Graner et al. 2003)
Serratia plymuthica	Endophyte	Induced Resistance	Cucumber	*Pythium ultimum*	(Benhamou et al. 2000)
Streptomyces sp.	Perennial ryegrass	1-N-methylalbono-ursin	*in vitro*	Not stated	(Gurney and Mantle 1993)
Streptomyces sp.	Mountain Laurel	Antibiotic	Laurel	*Pestalotiopsis sydowiana*	(Nishimura et al. 2002)

In most conventional biocontrol protocols, the agent is applied directly to the soil. Some biocontrol bacteria are capable of establishing populations in the soil (Reinhold-Hurek et al. 1986; McInroy and Kloepper 1995; Germida et al. 1998; Germida and Siciliano 2001), while others cannot compete with indigenous strains. Those that survive and proliferate may enter the root system at points where secondary roots emerge,

through the root epidermis near root hairs and wounds (Agarwal and Shende 1987; Gagné et al. 1987; Kobayashi and Palumbo 2000). Bacterial species able to enter the plant and flourish within the apoplastic space can establish populations within the plant and theoretically reduce the development of pathogen-caused disease (Benhamou et al. 2000; Chen et al. 2000; Tsuda et al. 2001). Bacterial endophytes, once inside a plant, can move from the site of entry to other plant parts (Hall et al. 1986; Marti et al. 1999). The way in which these endophytes move around in the plant is unknown but may relate to the use of cell wall degrading enzymes (Pleban et al. 1995; Pan et al. 1997).

The bacterial endophyte may exert direct or indirect effects on the growth and establishment of plant pathogens. Bacterial endophytes can produce and secrete extracellular substances that provide direct control over the growth and reproduction of phytopathogens. Some endophytes produce chitinases that dissolve the cell wall of pathogenic fungi (Pan et al. 1997) and cell wall digestive proteases (Pleban et al. 1995; Pan et al. 1997; Graner et al. 2003). Other endophytes can produce secondary metabolites, such as 1-N-methylalbonoursin (Gurney and Mantle 1993) and munumbicins A-D (Castillo et al. 2002), both produced by *Streptomyces* sp. with antibiotic properties. However, most *in vitro* and *in planta* studies documenting antagonism by bacterial endophytes have not determined the mode of protection (Brooks et al. 1994; Chen et al. 1995; Adhikari et al. 2001; Coombs et al. 2003).

A number of bacterial endophytes display *in vitro* and *in vivo* antibiotic activity and a few control fungal plant disease as well as commercial fungicides. *Stenotrophomonas maltophilia* produces an extracellular serine protease that protects sugar beets against *Pythium*-mediated damping-off disease at a rate equivalent to that by

chemical fungicides (Dunne et al. 2000). *Pseudomonas aureofaciens* TX-1 produces and secretes phenazine-1 carboxylic acid, and was as effective at controlling the dollar spot fungus (*Sclerotinia homeocarpa*), now *Lanzia* and *Moellerodiscus* spp., on creeping bentgrass (*Agrostis stolonifera* L. var. *palustris* [Huds.]) as the fungicides triadimefon and chlorothalonil (Powell et al. 2000). Extracellular chitin produced by *S. maltophilia* C3 controlled *Uromyces appendiculatus*, the causal agent of bean rust, to a degree comparable to that by thiophanate methyl or thiophanate methyl combined with manganese ethylenebisdithiocarbamate (Yuen 2001). In growth chamber studies, *P. aureofaciens* controlled dollar spot as well as did propiconazol but not as effectively as did azoxystrobin. *Enterobacter cloacae* controlled Pythium foliar blight on 7 to 10 week old ryegrass (*Lolium* L. spp.) plants comparable to iprodione and propiconazole (Uddin and Viji 2002). Not only can *S. maltophilia*, *P. aureofaciens*, and *E. cloacae* thrive as endophytes, they are also rhizosphere competent, making them, and other bacterial endophytes with similar attributes, promising biological control agents.

Additional advantages of using bacterial endophytes for biological control include the induction of a localized resistance response by some (Benhamou et al. 2000) and defense-enhancing ultrastructural modifications by others (Benhamou et al. 1996; M'Piga et al. 1997) in plants. In addition to the antifungal properties of endophytes, some endophytes stimulate plant growth (Gardner et al. 1984; Nejad and Johnson 2000; Barka et al. 2002). For example, seven bacterial endophyte species isolated from clover roots and potato tubers promoted plant growth in potato and displayed *in vitro* antagonism towards *Rhizoctonia solani* (Sturz et al. 1998). The mechanisms of plant growth enhancement were not determined in these studies, but may have to do with the control of

the disease pathogen itself or the production of hormonal substances that increase plant growth rates.

The optimal biological control organism will increase plant biomass and yield, protect the host against disease at the site of infection, and induce disease resistance throughout the plant. Systemic resistance can be elicited by lipopolysaccharides from the outer cell wall of Gram-negative bacteria (Newman et al. 1995; Coventry and Dubery 2001). The elicitation produces signaling compounds such as salicylic acid, jasmonic acid, and ethylene (Van Loon and van Strien 1999). These substances trigger a complex signaling cascade that increases expression of pathogenesis-related proteins including chitinases and proteases. This altered gene expression has morphological and biochemical consequences, including production of secondary metabolites such as siderophores (Becker and Cook 1988; Loper 1988), coenzymes (Palva et al. 1993), cyanic acid, and several antibiotics (Ahl et al. 1986; Duffy and Defago 1999). The complete range of mechanisms and signaling pathways involved in systemic resistance have not been fully determined and remain an active area of research that promises to aid development of biological control agents.

There are precedents for use of bacteria as successful biological control agents for plant diseases and include the commercial products: Companion (*B. subtilis* (Ehrenberg 1835) Cohn 1872 strain GB03, Growth Products, White Plains, NY), Subtilex (*B. subtilis*, The MicroBio Group Ltd., Boulder, CO), Spot-Less (*P. aureofaciens* Kluyver 1956 strain TX-1, Eco Soil Systems, Inc., San Diego, CA) (Fravel 2000), and Serenade (*B. subtilis* QST-713, AgraQuest Inc., Davis, CA) (Ritter 2003) all possess a broad range fungicidal activity.

Even with the advantages of using bacterial endophytes as biological control agents, there are some challenges to meet. Bacterial endophytes possessing antibiotic properties can display different levels of antagonism on different nutrient media, suggesting that the nutritional environment is important for the expression of antagonism (James and Gutterson 1986; Milner et al. 1996; Duffy and Defago 1999).

The majority of initial studies assessing the antibiosis of endophytic bacteria are executed under strictly controlled conditions in the laboratory and or greenhouse (Pleban et al. 1995; Nejad and Johnson 2000; Tsuda et al. 2001; Coombs et al. 2003) but corresponding activity may be absent under field conditions. The reasons for this may be several fold. The field environment is typically more complex and diverse than that found in the laboratory or even the greenhouse. Laboratory cultured bacteria in field conditions may fail to compete with the resident bacteria. The variable and diverse environment in the field may not support the expression of the antimicrobial activity (Sivan and Chet 1992; Deacon and Berry 1993; Bacon and Hinton 2002; Handelsman 2002). Although a few biocontrol agents have performed successfully in field trials (Gnanamanickam and Mew 1992; Raupach and Kloepper 1998; Dunne et al. 2000) there remain many obstacles to the successful development of a biocontrol agent.

There is an enormous untapped pool of endophytic bacteria with promise as biological control agents. Important considerations for developing endophytes as biological control agents include: maintaining high populations of specific pathogen acting endophytes in plant tissues, assuring that antagonistic properties of endophytes are expressed in the plant, optimizing or directing the colonization of endophytes to specific tissues, promoting the long term survival of the endophyte in the plant tissues, promoting

the expression of antifungal properties at levels sufficient for effective disease control. Additional difficulties in using endophytic species include the development of a large scale field-based application procedure. These represent important aspects for future research.

Molecular Characterization of Bacteria in Plants and Soils

The identification of bacterial endophytes is critical to the discovery and development of microbial biocontrol agents. The three methods most relied upon are morphology assessments, biochemical assays, and DNA sequence analysis. Other protocols discriminate bacteria based on analyses of the fatty acid composition or the G+C mol % of the genomic DNA. Some protocols apply to specific groups of bacteria, such as comparing sequences of the nitrogenase enzyme (*nif*HDK) of nitrogen-fixing microorganisms (Watson 1994).

The traditional and most straightforward method for bacterial identification is documenting morphological traits coupled with biochemical assays. Biochemical tests used to classify bacteria include, but are not limited to, the Gram stain reaction, aerobic or anaerobic growth, pH and temperature limits for minimum and maximum growth rates, and various nutritional requirements or responses to stress. A multiplexed approach to biochemical assays is provided by the Biolog GN MicroPlate coupled with the Biolog GN computer database (Biolog, Inc. Hayward, CA).

Morphological and biochemical traits can be plastic and are not as reliable for identifying organisms as information in the genetic code. Several popular approaches are based upon comparisons of DNA fragment lengths using gel electrophoresis. Genomic DNA fingerprints are often used to identify bacteria because they provide a high level of

taxonomic identification. Restriction fragment length polymorphism (RFLP) uses restriction enzymes to cut genomic DNA into fragments that are separated by gel electrophoresis to produce the DNA fingerprint. Classifications are made based on similarity of electrophoretic patterns to those from reference organisms.

Another DNA fingerprinting protocol called rep-polymerase chain reaction (rep-PCR) involves the PCR amplification of genomic DNA fragments using primers from repetitive sequences. Short repetitive DNA sequences are highly conserved, distributed sporadically throughout the bacterial genomic DNA, and can be specific to the strain level (Versalovic et al. 2004; de Bruijn 1992). Amplification of genomic DNA is initiated at one rep-PCR primer and is terminated at the next annealed primer, yielding fragments of different lengths. These fragments of genomic DNA are separated by gel electrophoresis to produce a DNA fingerprint. In the same manner as RFLP, the fingerprints are matched to a known organism and classification is based on pattern similarities. The drawbacks of genomic fingerprinting are: (1) an expensive computer program is needed for pattern comparisons, (2) these techniques are unable to resolve nucleotide sequence differences in fragments of similar length (3) there is an absolute need for reference organisms and (4) typically you can only run a limited number of DNA fingerprints on a given gel restricting the number of reliable comparisons.

One of the most powerful, rapid, inexpensive, reproducible, and thus popular, approaches for prokaryote classification is DNA sequencing of the 5S or 16S ribosomal DNA (rDNA). Both 5S and 16S ribosomal DNA have highly conserved and highly variable regions interspersed throughout the full DNA sequence. The highly conserved sequences are used as primers to amplify the highly variable regions. Nucleotide

sequences of the highly variable regions can be unique to the strain level, but are often only able to distinguish to the genus level. Nucleotide sequences can be used to determine similarities between organisms. The rDNA sequence of the unknown organism is matched through an algorithm such as BLAST (Thompson et al. 1994) to known DNA sequences in a database, such as the National Center for Biotechnology Information (NCBI) (http://www.ncbi.nlm.nih.gov) or Bio Informatic Bacterial Identification, version 2 (pbil.univ-lyon1.fr/bibi). The ribosomal DNA sequence database is expanding at a rapid rate, and it is becoming the first step in bacterial identification for many laboratories.

Techniques for Quantifying Fungi in Soils and Plant Tissues

Accurate quantification of fungal pathogens in soil and plant tissue was not possible until the development of real-time quantitative PCR techniques. Higuchi et al. (1993) were the first to document DNA amplification with real-time PCR. Since then, numerous molecular applications have been developed which include mRNA expression studies, DNA copy number measurements in genomic or viral DNAs, and expression analysis of specific splice variants of genes (Ginzinger 2002), quantification of human pathogenic bacteria, protozoans, and fungi (Filion et al. 2003), detection and quantification of bacteria and phytopathogenic fungi in plant tissues (Hristova et al. 2001; Schner et al. 2001), plant extracts (Weller et al. 2000), seeds (Filion et al. 2003), soil (Stults et al. 2001; Schena et al. 2002), soil and potato tubers (Cullen et al. 2001; Lees et al. 2002) and potato peels, tuber washings, and soil (Bell et al. 1999). Real-time quantitative PCR has led to better understanding of pathogen distributions and plant-pathogen interactions, and holds much promise for even greater advances in the future.

Real-time quantitative PCR uses a thermal cycler with a 96 or 384 well format equipped with a fluorescence source and detector. Measurements are made by detecting the increase in fluorescence accompanying PCR amplification. Fluorescence is induced by either a laser (ABI Prism 7700, Applied Biosystems, Foster City, CA) or blue-light emitting diode (Lightcycler, Roche Molecular Biochemicals, Mannheim, Germany). When DNA-binding dyes, molecular beacons (Stratagene, La Jolla, CA), hybridization probes, or hydrolysis probes adhere to the target DNA, fluorescence is detected after every PCR cycle.

The different types of fluorescent strategies have varying degrees of selectivity for detecting a target DNA sequence. Fluorescent DNA-binding dyes, such as SYBR Green, are the least selective of the four methods because they intercalate double stranded DNA and can bind to primer-dimers and non-target as well as target DNA. Also, more than one fluorescent molecule can bind to amplified DNA and the amount of fluorescent signal is determined by the mass of double stranded DNA.

Molecular beacons, hybridization, and hydrolysis probes have DNA sequences that complement and bind the target DNA sequence and thus are more selective than fluorescent dyes that can bind to all double-stranded PCR products. Molecular beacons are probes that hybridize to the DNA amplicon. Initially, the molecular beacon takes the shape of a stem-loop structure with a fluorescent marker and quencher at opposite arms. There is no fluorescence in the stem-loop structure because the quencher is in close proximity to the fluorescent molecule allowing the quencher to absorb the fluorescence and release the energy as heat. The nucleic acid sequence in the loop of the molecular beacon is complementary to the DNA amplicon. When the molecular beacon binds to the

DNA amplicon the fluorescent marker and quencher are separated. The distance is adequate to remove fluorescence quenching, and the increase in fluorescence is detected and recorded by the fluorescence detector.

Hybridization probes involve two separate probes. One probe is labeled with the fluorescent dye fluorescein which emits green light when excited. When a fluorophore is nearby, energy is transferred from the excited fluorescein to the fluorophore, which emits a different (red) wavelength. Detection of a target DNA sequence is accomplished by labeling a second probe with the fluorophore, which does not fluoresce when irradiated with the wavelength used for fluorescein excitation. When the two probes are suspended in the PCR mix, the only molecule to fluoresce is fluorescein (fluoresces green). The fluorophore is too distant to be excited by the fluorescein. When the two probes hybridize "tail to head" on the target DNA, the fluorophore is close to the fluorescein, accepts energy from the excited fluorescein, and emits energy as red light.

Hydrolysis probes, such as the TaqMan® Assay (Applied Biosystems, Foster City, CA), were designed to detect short target DNA sequences (about 25 nucleotides) that are so short that fluorescence quenching would still occur even after hybridization to the amplicon. As was the case with molecular beacons, TaqMan® probes have a fluorescent dye at one end of the probe and a quencher molecule at the other. The probe binds to the target DNA and hydrolysis by the 5' nuclease activity of the DNA polymerase releases both the quencher and the fluorescent molecule. The latter is detected, free from the quenching effects of the quencher.

Research Objectives

The first objective of this research was to identify culturable bacterial endophytes from crown tissue of bermudagrass, comparing two bermudagrass cultivars: Midlawn, SDS resistant, and Tifgreen, SDS susceptible. The effects of *O. herpotricha* infection on the culturable endophytes were also investigated. A diverse assortment of bacteria capable of colonizing bermudagrass offers greater potential for developing approaches for biological control of SDS, particularly if some of these endophytes express antifungal properties.

The second research objective was to individually assess *in vitro* antagonism of each bacterial endophyte towards the SDS fungus, *O. herpotricha*, in the hope of finding a candidate(s) that can be developed as a biological control agent. The development of a biological control agent for SDS is needed because traditional methods: resistant cultivars, fungicides, and turf management practices, were not successful in controlling SDS in Oklahoma and Kansas.

The third research objective was to develop a real-time PCR assay with TaqMan® chemistry to detect and quantify *O. herpotricha* DNA in plant and soil samples to quantify this pathogen. Such information would be useful in studies of the development and spread of SDS.

The fourth research objective was to use the real-time PCR assay to determine if there is a relationship between *O. herpotricha* infection and the resistance of bermudagrass cultivars and to determine the spatial distribution of *O. herpotricha* in plant and soil samples. The data gleaned from the real-time PCR assay with TaqMan®

chemistry can lead to a better understanding about the relationship between SDS and bermudagrass.

BIBILOGRAPHY

Adams, P. D. and J. W. Kloepper (2002). "Effect of host genotype on indigenous bacterial endophytes of cotton (*Gossypium hirsutum* L.)." Plant and Soil 240(1): 181-198.

Adams, W. A. and R. J. Gibbs (1994). Natural Turf for Sport and Amenity: Science and Practice. New Zealand, CAB International.

Adhikari, T. B., C. M. Joseph, et al. (2001). "Evaluation of bacteria isolated from rice for plant growth promotion and biological control of seedling disease of rice." Can. J. Microbiol. 47: 916-924.

Agarwal, S. and S. T. Shende (1987). "Tetrazolium reducing microorganisms inside the root of *Brassica* species." Curr. Sci. 56: 187-188.

Ahl, P., C. Voisard, et al. (1986). "Iron bound-siderphores, cyanic acid, and antibiotics involved in suppression of *Thielaviopsis basicola* by a *Pseudomonas fluorescens* strain." J. Phytopathol. 116: 121-134.

Alderson, J. and W. C. Sharp. (1994). Grass Varieties in the United Sates: Agriculture Handbook No. 170. United States Department of Agriculture. Lewis Publishers, Boca Raton, NJ.

Anonymous (1987). Thiophanate-methyl: substance file from the Integrated Risk Information System (IRIS). United States Environmental Protection Agency. www.epa.gov/ngispgm3/iris/subst/0117.htm

Anonymous (1997a). Flora of North America Vol. 1. Oxford University Press, NY.

Anonymous (1997b). Abound Flowable: Material Safety Data Sheet. Zeneca Agricultural Products, Wilmington, DE. p 2.

Anonymous (1997c). Patchwork: Material Safety Data Sheet. Riverdale Chemical Company. Glenwood, IL. p 4.

Anonymous (1998). Rubigan E. C. Fungicide: Material Safety Data Sheet. Dow AgroSciences LLC, Indianapolis, IN. p2.

Anonymous (1999a). 1999 Turfgrass pesticide suggestions. Texas Agricultural Extension. Texas A & M University.

Anonymous (1999b). Eagle WSP Fungicide: Material Safety Data Sheet. Rohm and Haas Company, Philadelphia, PA. p 11.

Anonymous (2000a). Rubigan A. S. Specimen Label. Dow AgroSciences LLC. Indianapolis, IN. p 6.

Anonymous (2000b). 3336WP Specimen Label. Cleary Chemical Corporation. Dayton, NJ. p 4.

Anonymous (2000c). Abound Specimen Label. Zeneca Ag Products, Inc., Wilmington, DE. p 5.

Anonymous (2000d). Bravo 5000 Specimen Label. Zeneca Ag Products, Inc., Wilmington, DE. p 6.

Anonymous (2000e). Tilt: Material Safety Data Sheet. Novartis Crop Protection, Inc. Greensboro, NC. p 6.
Anonymous (2000f). Commercial biocontrol products for use against soilborne crop diseases. National Sustainable Agriculture Information System. attra.ncat.org/attra-pub/microbials.html.
Anonymous (2001). Common and trade names of fungicides, insecticides, and miticides. The Texas A&M University.
Araújo, W. L., J. Marcon, et al. (2002). "Diversity of endophytic bacterial populations and their interaction with *Xylella fastidiosa* in citrus plants." Appl. Environ. Microbiol. 68: 4906-4914.
Ayensu, E. S. (1981). Medicinal Plants of the West Indies. Reference Publications, Inc.
Bacon, C. W. and D. M. Hinton (2002). "Endophytic and biological control potential of *Bacillus mojavensis* and related species." Biological Control 23(3): 274-284.
Baldani, J. I., V. L. D. Baldani, et al. (1986). "Characterization of *Herbaspirillum seropedicae* gen. nov., sp. nov. a root-associated nitrogen-fixing bacterium." Intl. J. Syst. Bacter. 36: 86-93.
Barka, E. A., S. Gognies, et al. (2002). "Inhibitory effect of endophyte bacteria on *Botrytis cinerea* and its influence to promote the grapevine growth." Biol. Control 24: 135-142.
Barraquio, W. L., L. Revilla, et al. (1997). "Isolation of endophytic diazotrophic bacteria from wetland rice." Plant and Soil 194: 15-24.
Beard, J. B. (1973). Turfgrass: Science and Culture. Boca Raton, NJ, Prentice-Hall, Inc.
Becker, J. O. and R. J. Cook (1988). "Role of siderphores in suppression of *Pythium* species and production of increased-growth response of wheat by fluorescent pseudomonads." Phytopathology 78: 778-782.
Bell, C. R., G. A. Dickie, et al. (1995). "Endophytic bacteria in grapevine." Can. J. Microbiol. 41: 46-53.
Bell, K. S., J. Roberts, et al. (1999). "Detection and quantification of *Spongospora subterranea* f. sp. *subterranea* in soils and on tubers using specific PCR primers." Eur. J. Plant Pathol. 905-915.
Benhamou, N., S. Gagné, et al. (2000). "Bacterial-mediated induced resistance in cucumber: beneficial effect of the endophytic bacterium *Serratia plymuthica* on the protection against infection by *Pythium ultimum*." Phytopathology 90(1): 45-56.
Benhamou, N., J. W. Kloepper, et al. (1996). "Induction of defense-related ultrastructural modifications in pea root tissues inoculated with endophytic bacteria." Plant Physiol. 112: 919-929.
Berg, G., P. Marten, et al. (1996). "*Stenotrophomonas maltophilia* in the rhizosphere of oilseed rape: Occurance, characterization and interaction with phytopathogenic fungi." Microbiological Research 151(1): 19-27.
Boddey, R. M., S. Urquiaga, et al. (2003). "Endophytic nitrogen fixation in sugarcane: present knowledge and future applications." Plant and Soil 252: 139-149.
Boulos, L. (1983). Medicinal Plants of North Africa. Reference Publications, Inc.
Braun, E. L. (1967). The Monocotyledoneae, Cat-tails to Orchids. Ohio, The Ohio State University Press.

Brooks, D. S., C. F. Gonzalez, et al. (1994). "Evaluation of endophytic bacteria as potential biological control agents for oak wilt." Biological Control 4: 373-381.
Brummitt, R. K. and C. E. Powell (1992). Plant Names. Kent, UK, Royal Botanic Gardens, Kew.
Busey, P. and A. E. Dudeck (2005). Bermudagrass varieties. University of Florida. 2005. www.grove.ufl.edu/~turf/bermvars/.
California Department of Food and Agriculture. (2005). "Noxious Weeds." www.cdfa.ca.gov/phpps/ipc/noxweedinfo/noxweedinfo_hp.htm.
Castillo, U. F., G. A. Strobel, et al. (2002). "Munumbicins, wide-spectrum antibiotics produced by *Streptomyces* NRRL 30462, endophytic on *Kennedia nigriscans*." Microbiology 148: 2675-2685.
Chanway, C. P. (1996). "Endophytes: There're not just fungi!" Canadian Journal of Botany 74: 3321-322.
Chastagner, G. A. and W. Hammer (1997). "Factors affecting the *in vitro* production of pseudothecia of *Leptosphaeria korrae*." International Turfgrass Society Research Journal 8: 847-861.
Chen, C., E. M. Bauske, et al. (1995). "Biological control of Fusiarum wilt on cotton by use of endophytic bacteria." Biological Control 5: 83-91.
Chen, C., R. R. Belanger, et al. (2000). "Defense enzymes induced in cucumber roots by treatment with plant growth-promoting rhizobacteria (PGPR) and *Pythium aphanidermatum*." Physiol. Mol. Plant Pathol. 56: 13-23.
Clarke, J. H., W. S. Clark, et al. (1997). "Strategies for the prevention of development of pesticide resistance in the UK - Lessons for and from the use of herbicides, fungicides and insecticides." Pesticide Science 51: 391-397.
Coombs, J. T., P. P. Michelsen, et al. (2003). "Evaluation of endophytic actinobacteria as antagonists of *Gaeumannomyces graminis* var. *tritici* in wheat." Biol. Control in press.
Correll, D. S. and M. C. Johnston (1970). Manual of the Vascular Plants of Texas. Renner, TX, Texas Research Foundation.
Coventry, H. S. and I. A. Dubery (2001). "Lipopolysaccharides from *Burkholderia cepacia* contribute to an enhanced defensive capacity and induction of pathogenesis-related proteins in *Nicotinae tabacum.*" Physiol. Mol. Plant Pathol. 58: 149-158.
Cribb, A. B. and J. W. Cribb (1981). Wild Medicine in Australia. Sydney, Collins.
Cullen, D. W., A. K. Lees, et al. (2001). "Conventional PCR and real-time quantitative PCR detection of *Helminthosporium solani* in soil and on potato tubers." Eur. J. Plant Pathol. 107: 387-398.
Dastur, J. F. (1950). Medicinal Plants of India and Pakistan. Bombay, D. B. Taraporevala Sons & Co. Ltd.
de Bruijn, F. J. (1992). "Use of repetitive (repetitive extragenic palindromic and enterobacterial repetitive intergeneric consensus) sequences and the polymerase chain reaction to fingerprint the genomes of *Rhizobium meliloti* isolates and other soil bacteria." App. Environ. Microbiol. 58(7): 2180-2187.
Deacon, J. W. and L. A. Berry (1993). "Biocontrol of soil-borne plant pathogens: concepts and their application." Pestic. Sci. 37: 417-426.

Deputy, J., D. Hensley, et al. (1998). Bermudagrass. Manoa, University of Hawaii at Manoa, Cooperative Extension Service. p 4.
Dernoeden, P. H. (2000). Maryland turfgrass disease control recommendations. Agronomy Mimeo 80. University of Maryland. iaa.umd.edu/umturf.
Dernoeden, P. H. (1999). A new fungal disease of creeping bentgrass. www.gcsaa.org/gem/1999/jun99/06creeping.html.
Dong, Z., M. J. Canny, et al. (1994). "A nitrogen-fixing endophyte of sugarcane stems: a new role for the appoplast." Plant Physiol. 105: 1139-1147.
Duble, R. L. (1996). Turfgrasses: Their Management and Use in the Southern Zone. College Station, TX, Texas A&M University Press.
Duffy, B. K. and G. Defago (1999). "Environmental factors modulating antibiotic and siderphore biosynthesis by *Pseudomonas fluorescens* biocontrol strains." Applied and Environmental Microbiology 65(6): 2429-2438.
Duke, J. A. and E. S. Ayensu (1985). Medicinal Plants of China. Reference Publications, Inc.
Dunne, C., Y. Moenne-Loccoz, et al. (2000). "Overproduction of an inducible extracellular serine protease improves biological control of *Pythium ultimum* by *Stenotrophomonas maltophilia* strain W81." Microbiology-UK 146: 2069-2078.
Endo, R. M., D. H. Ohr, et al. (1985). "*Leptosphaeria korrae*, a cause of the spring dead spot disease of bermudagrass in California." Plant Disease 69: 235-237.
Engelhard, M., T. Hurek, et al. (2000). "Preferential occurrence of diazotrophic endophytes, *Azoarcus* spp., in wild rice species and land races of *Oryza sativa* in comparison with modern races." Environ. Microbiol. 2: 131-141.
Fermanian, T. W., M. Shurtleff, R. Randell et al. (2003). Controlling Turfgrass Pests. Prentice-Hall, Upper Saddle River, NJ. p 554.
Filion, M., M. St-Arnaud, et al. (2003). "Direct quantification of fungal DNA from soil substrate using real-time PCR." Journal of Microbiological Methods 53: 67-76.
Fravel, D. (2000). Commercial biocontrol products for use against soilborne crop diseases. www.barc.usda.gov/psi/bpdl/bpdlprod/bioprod.html.
Gagné, S., C. Richard, et al. (1987). "Xylem-residing bacteria in alfalfa roots." Can. J. Microbiol. 33: 996-1000.
Gardner, J. M., J. L. Chandler, et al. (1984). "Growth promotion and inhibition by antibiotic-producing fluorescent pseudomonads on citrus roots." Plant and Soil 77: 103-113.
Gardner, J. M., A. W. Feldman, et al. (1982). "Identify and behavior of xylem-residing bacteria in rough lemon roots of Florida citrus trees." Appl. Environ. Microbiol. 43: 1335-1342.
Germida, J. J. and S. D. Siciliano (2001). "Taxonomic diversity of bacteria associated with the roots of modern, recent and ancient wheat cultivars." Biol. Fertil. Soils. 33(5): 410-415.
Germida, J. J., S. D. Siciliano, et al. (1998). "Diversity of root-associated bacteria associated with field-grown canola (*Brassica napus* L.) and wheat (*Triticum aestivum* L.)." FEMS Microbiol. Ecol. 26: 43-50.
Giesler, L. J. and G. Y. Yuen (1998). "Evaluation of *Stenotrophomonas maltophilia* strain C3 for biocontrol of brown patch disease." Crop Protect. 17(6): 509-513.

Ginzinger, D. G. (2002). "Gene quantification using real-time quantitative PCR: An emerging technology hits the mainstream." Experimental Hematology 30: 503-512.

Gnanamanickam, S. S. and T. W. Mew (1992). "Biological control of blast disease of rice (*Oryza sativa* L.) with antagonistic bacteria and its mediation by a *Pseudomonas* antibiotic." Ann. Phytopath. Soc. Japan 58: 380-385.

Gould, F. W. (1973). Grasses of Southwestern United States. Tucson, AZ, The University of Arizona Press.

Graner, G., P. Persson, et al. (2003). "A study on microbial diversity in different cultivars of *Brassica napus* in relation to its wilt pathogen, *Verticillium longisporum*." FEMS Microbiol. Ecol. 224(2): 269-276.

Green II, D. E., J. D. Fry, et al. (1993). "Pathogenicity of *Rhizoctonia solani* AG-2-2 and *Ophiosphaerella herpotricha* on zoysiagrass." Plant Disease 77: 1040-1044.

Gurney, K. A. and P. G. Mantle (1993). "Biosynthesis of 1-*N*-methylalbonoursin by an endophytic *Streptomyces* sp. isolated from perennial ryegrass." J. Nat. Prod. 56: 1194-1198.

Hagan, A. (1997). "Control of spring dead spot and bermudagrass decline." Alabama Cooperative Extension System ANR-371. p 3. www.ces.edu/dept/extcomm/publications/anr/anr-371/anr-371.htm

Hall, T. J., L. R. Schreiber, et al. (1986). "Effects of xylem-colonizing *Bacillus* spp. on Vetricillium wilt in maples." Plant Disease 70: 521-524.

Hallmann, J. (2001). Plant interactions with endophytic bacteria. In Biotic Interactions in Plant-Pathogen Associations. Ed. N. J. Spence. CAB International. p 87-119.

Handelsman, J. (2002). Future trends in biocontrol. In Biological Control of Crop Diseases. Ed. S. S. Gnanamanickam. New York, Marcel Dekker, Inc. p 443-448.

Hanson, A. A. (1972). Grass Varieties in the United States: Agriculture Handbook No. 170. United States Department of Agriculture. Washington D. C.

Higuchi, R., C. Fockler, et al. (1993). "Kenetic PCR analysis: Real-time monitoring of DNA amplification reactions." Bio/Technology 11: 1026-1030.

Hinton, D. M. and C. W. Bacon (1995). "*Enterobacter cloacae* is an endophytic symbiont of corn." Mycopathologia 129(2): 117-125.

Hollis, J. P. (1951). "Bacteria in healthy potato tissue." Phytopathology 41: 350-366.

Hristova, K. R., C. M. Lutenegger, et al. (2001). "Detection and quantification of methyl *tert*-butyl ether-degrading strain MP1 by real-time TaqMan® PCR." Applied and Environmental Microbiology 67(11): 5154-5160.

Hurek, T., L. L. Handley, et al. (2002). "*Azoarcus* grass endophytes contribute fixed nitrogen to the plant in an unculturable state." Molec. Plant Microbe Interact. 15: 233-242.

Jackson, N. (1993). Geographic distribution, host range, and symptomatology of patch diseases casued by soilborne ectotrophic fungi. In Turfgrass Patch Diseases Caused by Ectotrophic Root-Infecting Fungi. Eds. B. B. Clark and A. B. Gould. St. Paul, APS Press. p 17-39.

Jacobs, M. J., W. M. Bugbee, et al. (1985). "Enumeration, location, and characterization of endophytic bacteria within sugar beet roots." Can. J. Bot. 63: 1262-1265.

James, D. W. and N. I. Gutterson (1986). "Multiple antibiotics produced by *Pseudomonas fluorescens* HV37a and their differential regulation by glucose." Applied and Environmental Microbiology 52(5): 1183-1189.
Jayaweera, D. M. A. (1981). Medicinal Plants (Ingidenous and Exotic) Used in Ceylon. Colombo, The National Science Council of Sri Lanka.
Kageyama, B., M. Kakae, et al. (1992). "*Pantoea puctata* sp. nov., *Patoea citrea* sp. nov., and *Pantoea terrea* sp. nov. isolated from fruit and soil samples." Int. J. Syst. Bacteriol. 42(2): 203-210.
Knutson, D. M. (1973). "The bacteria in sapwood, wetwood, and heartwood of trembling aspen (*Populus tremuloides*)." Canadian Journal of Botany 51: 498-500.
Kobayashi, D. Y. and J. D. Palumbo (2000). Bacterial endophytes and their effects on plants and uses in agriculture. In Microbial Endophytes. Eds.C. W. Bacon and J. F. W. Jr. New York, Marcel Dekker. p 199-233.
Kovtunovych, G., O. Lar, et al. (1999). "Correlation between pectate lyase activity and ability of diazotrophic *Klebsiella oxytoca* VN 13 to penetrate into plant tissues." Plant and Soil 215: 1-6.
Kusel, K., H. C. Pinkard, et al. (1999). "Acetogenic and sulfate-reducing bacteria inhabiting the rhizoplane and deep cortex cells of the sea grass *Halodule wrightii*." Applied and Environmental Microbiology 65: 5117-5123.
Landshoot, P. J. (1993). Taxonomy and biology of ectotrophic root-infecting fungi associated with patch diseases of turfgrasses. In Turfgrass Patch Diseases Caused by Ectotrophic Root-Infecting Fungi. Eds. B. B. Clarke and A. Gould, B. St. Paul, MN, APS Press.
Lees, A. K., D. W. Cullen, et al. (2002). "Development of conventional and quantitative real-time PCR assays for the detection and identification of *Rhizoctonia solani* AG-3 in potato and soil." Plant Pathol. 51: 293-302.
Loper, J. E. (1988). "Role of fluorescent siderophore production in biological control of *Pythium ultimum* by a *Pseudomonas fluorescens* strain." Phytopathology 78: 166-172.
Lucas, L. T. and A. H. Bruneau (1995). Diseases of warm-season grasses. ces.ncsu.edu/turfFiles/pubs/patho/ag360.html.
M'Piga, P., R. R. Belanger, et al. (1997). "Increased resistance to *Fusarium oxysporum* f. sp. *radicis-lycopersici* in tomato plants treated with the endophytic bacterium *Pseudomonas fluorescens* strain 63-28." Physiol. Mol. Plant Pathol. 50: 301-320.
Mantell, S. H. (1998). "Microbes intimately associated with tissue and cell cultures of tropical *Dioscorea* yams." Plant Cell Tiss. Org. Cult. 52: 47-52.
Marti, R., J. Cubero, et al. (1999). "Evidence of migration and endophytic presence of *Agrobacterium tumefaciens* in rose plants." Eur. J. Plant Pathol. 105: 39-50.
Martin, D. and B. Hudgins (1998). Managing spring dead spot disease of bermudagrass, F. 7665. Oklahoma State University. Oklahoma Cooperative Extension Service.
Martin, S. B. (1999). Disease Control. Clemson University. www.sodsolutions.com/turfmgt.disease.html.
Mattila, A. M. (2001). "Endophytes in the buds of Scots pine (*Pinus sylvestris* L.)." Acta Universitatis Ouluensis A Scientiae Rerum Naturalium 369: 1-55.

McCarty, L. B. and L. T. Lucas (1989). "*Gaeumannomyces graminis* associated with spring dead spot of bermudagrass in the southern United States." Plant Disease 73: 659-661.
McInroy, J. A. and J. W. Kloepper (1995). "Survey of indigenous bacterial endophytes from cotton and sweet corn." Plant and Soil 173: 337-342.
Milner, J. L., L. Silo-Suh, et al. (1996). "Production of kanosamine by *Bacillus cereus* UW85." Applied and Environmental Microbiology 62(8): 3061-3065.
Mocali, S., E. Bertelli, et al. (2003). "Fluctuation of bacteria isolated from elm tissues during different seasons from different plant organs." Research in Microbiology 154(2): 105-114.
Mundt, J. O. and N. F. Hinkle (1976). "Bacteria within ovules and seeds." Applied and Environmental Microbiology 32(5): 694-698.
Nejad, P. and P. A. Johnson (2000). "Endophytic bacteria induce growth promotion and wilt disease suppression in oilseed rape and tomato." Biol. Control 18: 208-215.
Newman, M.-A., M. J. Daniels, et al. (1995). "Lipopolysaccharide from *Xanthomonas campestris* induces defense-related gene expression in *Brassica campestris*." Molec. Plant Microbe Interact. 8(5): 778-780.
Nishimura, T., A. Meguro, et al. (2002). "An endophytic actinomycete, *Streptomyces* sp,. AOK-30, isolated from mountain laurel and its antifungal activity." Journal of General Plant Pathology 68(4): 390-397.
O'Gorman, D., B. Xue, et al. (1994). "Detection of *Leptosphaeria korae* with the polymerase chain reaction and primers from the ribosomal internal transcribed spacers." Can. J. Bot. 72: 342-346.
Oudhia, P. (2001). Doob (*Cynodon dactylon*): Traditional Medicinal Uses in India, Purdue University, Horticulture Department. 2001. www.hort.purdue.edu/newcrop/CropFactSheets/doob.html.
Palva, T. K., K.-O. Holmstrom, et al. (1993). "Induction of plant defense response by exoenzymes of *Erwinia carotovora* subsp. *carotovora*." Molec. Plant Microbe Interact. 6(2): 190-196.
Pan, M. J., S. Rademan, et al. (1997). "Ultrastructural studies on the colonization of banana tissue and *Fusarium oxysporum* f. sp. *cubense* Race 4 by the endophytic bacterium *Burkholderia cepacia*." J. Phytopathol. 145: 479-486.
Parke, J. L. (1991). Root colonization by indigenous and introduced microorganisms. Beltsville Symposia in Agricultural Research, Beltsville, MD, Kluwer Academic Publishers.
Philipson, M. N. and I. D. Blair (1957). "Bacteria in clover root tissue." Can. J. Microbiol. 3: 125-129.
Pleban, S., F. Ingel, et al. (1995). "Control of *Rhizoctonia solani* and *Sclerotium rolfsii* in the greenhouse using endophytic *Bacillus* spp." European Journal of Plant Pathology 101: 665-672.
Powell, J. F., J. M. Vargas, et al. (2000). "Management of dollar spot on creeping bentgrass with metabolites of *Pseudomonas aureofaciens* (TX-1)." Plant Disease 84(1): 19-24.
Quadt-Hallmann, A., N. Benhamou, et al. (1997). "Bacterial endophytes in cotton: mechanisms of entering the plant." Can. J. Microbiol. 43: 577-582.

Raupach, G. S. and J. W. Kloepper (1998). “Mixtures of plant growth-promoting rhizobacteria enhance biological control of multiple cucumber pathogens.” Phytopathology 88: 1158-1164.
Reinhold-Hurek, B., T. Hurek, et al. (1986). “Close association of *Azospirillum* and diazotrophic rods with different root zones of Kallar grass.” Appl. Environ. Microbiol. 52: 520-526.
Reiter, B., U. Pfeifer, et al. (2002). “Response of endophytic bacterial communities in potato plants to infection with *Erwinia carotovora* subsp. *atroseptica*.” Appl. Environ. Microbiol. 68: 2261-2268.
Ritter, S. K. (2003). "Green rewards." Chem. Eng. News: 30-35.
Rogerson, C. T. (1958). "Diseases of grasses in Kansas: 1956-1957." Plant Disease Reporter. 42(3) 346-353.
Sato, M., W. Wei, et al. (2000). “Isolation and characterization of bacteria from colonies exuded from "germ-free" mulberry shoots cultured *in vitro*.” Journal of Sericultural Science of Japan 69(2): 147-152.
Sauer, K. M., S. H. Hulbert, et al. (1993). “Identification of *Ophiosphaerella herpotricha* by cloned DNA probes.” Am. Phytopath. So. 83: 97-102.
Schena, L., M. F. Sialer, et al. (2002). “Molecular detection of strain L47 of *Aureobasidium pullulans*, a biocontrol agent of postharvest diseases.” Plant Disease 86: 54-60.
Schner, H., L. Niessen, et al. (2001). “Real time detection of the *tri5* gene in *Fusarium* species by LightCycler™-PCR using SYBR® Green I for continuous fluorescence monitoring.” Int. J. Food Microbiol. 71: 53-61.
Shishido, M., B. M. Loeb, et al. (1995). “External and internal root colonization of lodgepole pine seedlings by two growth-promoting *Bacillus* strains originated from different root microsites.” Can. J. Microbiol. 41: 707-713.
Shurtleff, M. C., T. W. Fermanian and R. Randell. (1987). Controlling Turfgrass Pests. Prentice-Hall, Englewood Cliffs, NY p 449.
Sivan, A. and I. Chet (1992). Microbial control of plant diseases. in Environmental Microbiology. Ed. R. Mitchell. New York, Wiley: 335-354.
Smiley, R. W. (1993). Historical perspective of research on ectotrophic root-infecting pathogens of turfgrasses. In Turfgrass Patch Diseases Caused by Ectotrophic Root-Infecting Fungi. Eds. B. B. Clarke and A. B. Gould. St. Paul, MN, APS Press.
Smiley, R. W., P. H. Dernoeden and B. B. Clarke. (1992). Compendium of Turfgrass Diseases. 2 ed. APS Press, St. Paul, MN. p 98.
Smiley, R. W. and M. C. Fowler (1984). “*Leptosphaeria korrae* and *Phialophora graminicola* associated with Fusarium blight syndrome of *Poa pratensis* in New York.” Plant Disease 68: 440-442.
Stoltzfus, J. R., R. So, et al. (1997). “Isolation of endophytic bacteria from rice and assessment of their potential for supplying rice with biologically fixed nitrogen.” Plant and Soil 194: 25-36.
Stone, J. K., C. W. Bacon, et al. (2000). An overview of endophytic microbes: endophytism defined. In Microbial Endophytes. Eds.C. W. Bacon and J. White, J. F. NY, Marcel Dekker, Inc.

Strobel, G. A. (2003). "Endophytes as sources of bioactive products." Microbes Infect. 5: 535-544.
Stults, J. R., O. Snoeyenbos-West, et al. (2001). "Application of the 5' fluorogenic exonuclease assay (TaqMan®) for quantitative ribosomal DNA and rRNA analysis in sediments." Applied and Environmental Microbiology 67(6): 2781-2789.
Sturz, A. V., B. R. Christie, et al. (1998). "Associations of bacterial endophyte populations from red clover and potato crops with potential for beneficial allelopathy." Can. J. Microbiol. 44: 162-167.
Sturz, A. V., B. R. Christie, et al. (1999). "Endophytic bacterial communities in the periderm of potato tubers and their potential to improve resistance to soil-borne plant pathogens." Plant Pathol. 48: 360-369.
Sundaram, S., A. Arunakumari, et al. (1988). "Characterization of *Azospirilla* isolated from seeds of turf grass." Can. J. Microbiol. 34: 212-217.
Surette, M. A., A. V. Sturz, et al. (2003). "Bacterial endophytes in processing carrots (*Daucus carota* L. var. *sativus*): Their localization, population density, biodiversity and their effects on plant growth." Plant and Soil 253(2): 381-390.
Taliaferro, C. M., F. M. Rouquette, Jr. and P. Mislevy. (2004). Bermudagrass and Stargrass. In Warm-Season (C_4) Grasses. Eds. L. E. Moser, B. L. Burson, L. E. Sollenberger. American Society of Agronomy, Inc. Madison, WI. p 417-475.
Taliaferro, C. M. (1995). "Diversity and vulnerability of bermuda turfgrass species." Crop Science 35: 327-332.
Tapia-Hernandez, A., M. R. Bustillos-Cristales, et al. (2000). "Natural endophytic occurrence of *Acetobacter diazotrophicus* in pineapple plants." Microb. Ecol. 39: 49-55.
Thomas Jr., W. D. and R. W. Graham (1948). "Bacteria in apparently healthy pinto beans." Phytopathology 42: 214.
Thompson, J. D., D. G. Higgins, et al. (1994). "CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, positions-specific gap penalities and weight matrix choice." Nucleic Acids Res. 22: 4673-4680.
Tisserat, N. A. (1998). "Spring dead spot of bermudagrass." Kansas State University, Research and Extension. www.ksu.edu/plantpath/extension/facts/turf5/html
Tisserat, N. A., S. H. Hulbert, et al. (1994). "Selective amplification of rDNA internal transcribed spacer regions to detect *Ophiosphaerella korrae* and *O. herpotricha*." Phytopathology 84: 478-482.
Tisserat, N. A., F. B. Iriarte, et al. (2004). "Spring dead spot pathogens of bermudagrass." Golf Course Management April. p 117-120.
Tisserat, N. A., J. C. Pair, et al. (1989). "*Ophiosphaerella herpotricha*, a cause of spring dead spot of bermudagrass in Kansas." Plant Disease 73: 933-937.
Tsuda, K., Y. Kosaka, et al. (2001). "Evaluation of the enodphyte *Enterobacter cloacae* SM10 isolated from spinach roots for biological control against Fusarium wilt of spinach." Journal of General Plant Pathology 67(1): 78-84.
Turgeon, A. J. (1991). Turfgrass Management. Boca Raton, NJ, Prentice Hall.

Uddin, W. and G. Viji (2002). Biological control of turfgrass diseases. In Biological Control of Crop Diseases. Ed. S. S. Gnanamanickam. New York, Marcel Dekker: 313-337.

Van Loon, L. C. and E. A. van Strien (1999). "The families of pathogenesis-related proteins, their activities, and comparative analysis of PR-1 type proteins." Physiological and Molecular Plant Pathology 55: 85-97.

Vargus Jr., J. M. (1994). Management of Turfgrass Disease. 2nd ed. Lewis Publishing, Boca Raton, NJ.

Vasudevan, P., S. Kavitha, et al. (2002). Biological control of rice diseases. In Biological Control of Crop Diseases. Ed. S. S. Gnanamanickam. New York, Marcel Dekker, Inc. p 11-32.

Venkatasubbaiah, P., N. A. Tisserat, et al. (1994). "Metabolites of *Ophiosphaerella herpotricha*, a cause of spring dead spot of bermudagrass." Mycopathologia 128: 155-159.

Versalovic, J., M. Schneider, et al. (2004). "Genomic fingerprinting of bacteria using repetitive sequence-based polymerase chain reaction." Methods in Molecular and Cellular Biology 5: 25-40.

Vincelli, P. and A. J. Powell (2000). Chemical control of turfgrass diseases 2000, University of Kentucky. www.ca.uky.edu/agc/pubs/ppa/ppa1/ppa1.htm

Wadsworth, D. F. and H. C. Young Jr. (1960). "Spring dead spot of bermudagrass." Plant Disease Report. 44:516-518.

Watschke, T. L., P. H. Dernoeden and D. J. Shetlar. (1995). Advances in Turfgrass Science: Managing Turfgrass Pests. Lewis Publishers. Boca Raton, NJ. p 361.

Watson, J. R. (1994). Warm Season Turfgrasses. In Natural Turf for Sport and Amenity: Science and Practice. Eds. W. A. Adams and R. J. Gibbs. New Zealand, CAB International. p 377-396.

Watt, J. M. and M. G. Breyer-Brandwijk (1962). The Medicinal and Poisonous Plants of Southern and Eastern Africa. London, E. & S. Linvingstone Ltd.

Weller, S. A., J. G. Elphinstone, et al. (2000). "Detection of *Ralstonia solanacearum* strains with a quantitative, multiplex, real-time fluorogenic PCR (TaqMan®) assay." Appl. Environ. Microbiol. 66(7): 2852-2858.

Wetzel III, H. C., P. H. Dernoeden, et al. (1996). "Identification of darkly pigmented fungi associated with turfgrass roots by mycelial characteristics and RAPD-PCR." Plant Disease 80: 359-364.

Wetzel III, H. C., S. H. Hulbert, et al. (1999a). "Molecular evidence for the presence of *Ophiosphaerella narmari* n. comb., a cause of spring dead spot of bermudagrass in North America." Mycol. Res 103(8): 981-989.

Wetzel III, H. C., D. Z. Skinner, et al. (1999b). "Geographic distribution and genetic diversity of three *Ophiosphaerella* species that cause spring dead spot of bermudagrass." Plant Disease 83: 1160-1166.

Wu, Y. (2002). Personal communications. Oklahoma State University. Stillwater, OK.

Yuen, G. Y. (2001). "Bean rust biological control using bacterial agents." Crop Protect. 20: 395-402.

Zinniel, D. K., P. Lambrecht, et al. (2002). "Isolation and characterization of endophytic colonizing bacteria from agronomic crops and prairie plants." Appl. Environ. Microbiol. 68: 2198-2208.

CULTURABLE BACTERIAL ENDOPHYTES FROM SPRING DEAD SPOT RESISTANT AND SUSCEPTIBLE BERMUDAGRASS CULTIVARS AND THEIR ANTIFUNGAL PROPERTIES

ABSTRACT

Spring dead spot (SDS) is a devastating fungal disease of bermudagrass. The causal agents are *Ophiosphaerella korrae*, *O. herpotricha,* and *O. narmari*. These *Ophiosphaerella* spp. are soilborne, root-infecting fungi that live off of plant derived nutrients. Traditional pathogen control methods including the use of resistant bermudagrass cultivars, fungicides, and specific cultivation practices, have found limited success in controlling SDS in Oklahoma and Kansas. Biological control agents for SDS have yet to be developed. In hopes of finding culturable bacterial endophytes for development into biological control agents against SDS, bacterial endophytes were isolated from the crown tissue and rhizomes of SDS resistant Midlawn and susceptible Tifgreen bermudagrass cultivars, including SDS infected and non-infected plants. The Log_{10}CFU/g fresh wt was similar for non-infected Midlawn, infected Midlawn, and non-infected Tifgreen plants. Infection with *O. herpotricha* was lower in the Log_{10}CFU/g fresh wt. in infected Tifgreen plants when compared to non-infected Tifgreen plants. Endophytic bacteria were putatively identified to genera by sequencing contigs of their 16S rDNA and BLAST matching these sequences to the NCBI database. Seventy-seven Gram-negative and 51 Gram-positive culturable bacterial endophytes were sequenced. *Microbacterium* was the most frequently isolated genus from all 4 treatments followed by *Acidovorax*, *Stenotrophomonas*, and *Curtobacterium* isolated from 3 treatments. This is

the first report, to the best of my knowledge, of a *Geodermatophilus* sp. and an *Amycolatopsis* sp. as plant endophytes. Thirty-one culturable bacterial endophytes displayed *in vitro* antifungal activity toward *O. herpotricha*. There were more *Pseudomonas* and *Stenotrophomonas* antagonistic isolates than other antifungal genera. This is the first of *Chryseobacterium* sp. with *in vitro* antifungal attributes to the best of my knowledge.

INTRODUCTION

Bermudagrass [*Cynodon dactylon* (L.) Pers.] is a widely distributed warm-season, perennial, sod-forming turf and forage grass (Johns 2004; Turgeon 2005). It can tolerate a wide range of soil types and climatic conditions and forms coarse- to fine-textured turf and loose or dense sods (Fry and Huang 2004, Johns 2004). These attributes have popularized bermudagrass in the sunbelt of the United States and in Australia, New Zealand, and in tropical and subtropical regions of the world. The cultivars Midlawn and Tifgreen are hybrids of *C. dactylon* (L.) Pers. and the South African bermudagrass, *C. transvaalensis* Burtt-Davy. In contrast to *C. dactylon*, *C. transvaalensis* is found in a narrow geographic location being confined to the Transvaal and Orange areas of South Africa. *C. transvalensis* plants are smaller, and produce a fine textured, higher density sod than the typical *Cynodo*n sp. (Taliaferro 1992).

Three closely related *Ophiosphaerella* Spegazzini 1909 spp., *O. korrae* (J. C. Walker & A. M. Smith) Shoemaker & C. E. Babcock, *O. herpotricha* (Fr.:Fr.) J. C. Walker, and *O. narmari* Wetzel, Hulbert & Tisserat, the causal agents of Spring Dead Spot (SDS), are the greatest fungal threats to bermudagrass (Sauer et al. 1993; Taliaferro

1995). In the United States, SDS is a widespread disease confined to the northern limits of bermudagrass adaptation where autumn and winter temperatures induce dormancy in these plants (Turgeon 2005).

Ophiosphaerella spp. are soilborne, ectotrophic root-infecting fungi that live off of plant derived nutrients. Cool soil temperatures between 15 to 25 °C are optimal for SDS development (Fermanian et al. 2003). *O. herpotricha* is the main agent of SDS in Oklahoma (Tisserat et al. 2003). Though its primary host is bermudagrass, *O. herpotricha* also causes a patch disease in zoysiagrass (*Zoysia japonica* Steud.) and SDS in buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.) (Green II et al. 1993; Dernoeden 1999).

Several methods are used with limited success to control SDS in bermudagrass. Fungicides effective in Alabama, Kentucky, Maryland, and Texas are ineffective in controlling SDS in Kansas and Oklahoma (Anonymous 1999; Vincelli and Powell 2000; Dernoeden 2000; Hagan 1997; Martin and Hudgins 1998). Common alternatives to fungicides include selective cultivation practices and the use of SDS resistant bermudagrass cultivars. Turf management practices that help limit SDS include annual removal of excess thatch and core aerification, fertilization with ammonium sulfate and ammonium chloride with phosphorus and potassium during the growing season and ceasing 6 weeks prior to dormancy of bermudagrass (Watschke et al. 1995, Duble 1996, Fry and Huang 2004). Curiously, more intensively managed turfs are more susceptible to SDS (Shurtleff et al. 1987; Emmons 1995). Heavy applications of organic and inorganic fertilizers, nitrogen, phosphate, and potassium through the growing season and fertilizing after the first week in September will promote the growth of spring dead spot pathogens

(Emmonds 1995, Madison 1971). The use of resistant varieties is another alternative method for controlling SDS. Unfortunately, there are no completely resistant varieties of bermudagrass, although several promising lines are being currently developed. The most resistant cultivars include: 'Patriot' (OKC 18-4) [*Cynodon dactylon* L. (Pers.) X C. *transvaalensis* Burt-Davies], Midlawn, and Yukon, but resistance is only partial and may be overcome in severe SDS out-breaks.

One of the most SDS resistant bermudagrass cultivars is the vegetatively propagated cultivar, Midlawn, which was released in 1991 by the Kansas and Oklahoma Agricultural Experiment Stations (Alderson and Sharp 1994). Among seeded varieties cultivars Yukon and Riviera, the most resistant to SDS, were developed and released by Dr. Charles Taliaferro of the Oklahoma State Agricultural Experiment Station (Taliaferro et al. 2003; Taliaferro, personal communications). Susceptible cultivars include some high quality vegetatively propagated types, such as: Tifgreen and Tifway. Tifgreen is an F_1 hybred between *C. dactylon* collected from the fourth green at the Charlotte Country Club in North Carolina and *C. transvaalensis* from East Lakes Golf course in Atlanta, GA. Tifgreen was released in 1956 by the Georgia Agricultural Experiment Station (Burton 1991). Tifway, a natural hybrid (*C. dactylon* X *C. transvaalensis*) was fortuitously found in 1954 from a seed lot of *C. transvaalensis* from Johannesburg, South Africa and released in 1960 by the Georgia Coastal Plain Experimental Station and Plant Science Research Division, ARS (Burton 1991; Alderson and Sharp 1994).

Biological control is a widely accepted approach for controlling agricultural pests. This option is thought to be more environmentally friendly when compared to chemical fungicide treatments because biological control depends on natural processes. Another

advantage of biocontrol is that it may be less labor intensive and expensive when compared to alterations in cultivation practices. Furthermore, the development of biological control agents can require less time and expense compared to organic fungicides (Handelsman 2002). To further improve the effectiveness of the disease control, biological control agents may be used in conjunction with other disease control practices in an integrated pest management scheme (Vasudevan et al. 2002). Several bacterial biocontrol agents, isolated from soil and diseased tissue, are now currently used to control soilborne crop diseases (Sivan and Chet 1992; Deacon and Berry 1993; Jeger 2001).

Microorganisms that spend part or all of their life cycle inside a plant host without causing disease symptoms are called endophytes. Endophtyes that possess antifungal activity may serve as valuable resources as potential biological control agents. Bacterial endophytes are found in almost all plants species, including monocots, dicots, and conifers (Knutson 1973; Patriquin and Döbereiner 1978; Shishido et al. 1995; McInroy and Kloepper 1995a) as well as brackish water and marine plants, ferns, and thyloid bryophytes (McClung et al. 1983a; Kaplan and Peters 1998; Costa et al. 2001; Lovell 2002). Bacterial endophytes are found throughout the plant in an assortment of plant organs, such as leaves, stems, crowns, and roots. At the tissue level they are known to inhabit plant cortical and vascular tissues (Philipson and Blair 1957; Mundt and Hinkle 1976; Gagné et al. 1987; Dunleavy 1989).

Endophytes may function to enhance the development and well being of the plant. Examples of bacterial endophytes include nitrogen fixing bacteria (Sundaram et al. 1988; Suman et al. 2001; Hurek et al. 2002), bacteria with proven antagonistic attributes toward

fungal pathogens (Sturz et al. 1999; Adhikari et al. 2001; Coombs et al. 2003), bacteria that promote growth and development of plants and bacteria that induce systemic resistance in plants (Benhamou et al. 1996).

Studies of bacterial endophytes of graminaceous plants have concentrated on economically important grasses, such as maize, rice, sugar cane, and sorghum (Patriquin and Döbereiner 1978; Dong et al. 1994; Mukhopadhyay et al. 1996; Zinniel et al. 2002). Investigations of bacterial endophytes of less economically important grasses have been fewer in number. Examples include: endophytic bacteria in the sea grass *Halodule wrightii* Ascherson (Kusel et al. 1999) and endophytes from seeds and roots of turfgrasses (Sundaram et al. 1988). The associations of endophytes with various cell types in roots of grasses from Brazil was documented by Patriquin and Döbereiner (1978) using light microscopy. Diazotrophic endophytic bacteria "fix" dinitrogen and benefit plant and endophytes alike. Nitrogen fixing endophytic bacteria have been isolated from turfgrasses (Sundaram et al. 1988), Kallar grass (*Leptochloa fusca* (Linn.) Kunth) (Reinhold-Hurek et al. 1986; Hurek et al. 2002), and a Chesapeake Bay salt marsh grass, *Spartina alterniflora* Loisel (McClung et al. 1983b). However, studies of biological control in turfgrasses have mainly involved manipulation of rhizosphere bacteria and not endophytic bacteria (Nelson and Craft 1992; Zhang and Yuen 2000).

Bacterial endophytes that are antagonistic toward plant pathogens may constitute some of the most promising and versatile biological control agents because they survive in the surrounding plant rhizosphere, readily enter and colonize the host (Kageyama et al. 1992; Pleban et al. 1995; Tsuda et al. 2001), and retain their effectiveness over a period of time (Fravel 2000; Ritter 2003).

This thesis is the first study to document and putatively identify the culturable bacterial endophytes isolated from surface sterilized crown tissue of two cultivars of bermudagrass and to test these endophytes for antagonistic properties against the spring dead spot soilborne fungal pathogen, *O. herpotricha*. A major goal of this effort has been to identify promising candidates for use as a biological control agent.

MATERIALS AND METHODS

Plant Materials

The turfgrass plots were established in September 1997 and managed by the Oklahoma State University Turfgrass Research Center, Stillwater, Oklahoma, under the direction of Dr. Dennis Martin. SDS resistant Midlawn and susceptible Tifgreen cultivars of berumdagrass were used in this study. The turf plots were inoculated on September 25, 1997 using 5 *O. herpotricha* OK188-infected oat grains per inoculation site.

One sampling for characterization of endophytic bacteria was performed in the fall from these plots when it was thought that the disease was most active. Location of a diseased area was determined the previous spring based on the location of a patch of dead turf. The center of the patch was marked with a metal coin buried several inches within the sod at the time of inoculation. The marker-coin was necessary because during the summer months the neighboring bermudagrass recolonized the patch making it disappear. During autumn sampling, the coin marker was found using a standard metal detector. Turf plugs were removed by inserting a metal 2.5 cm diameter X ten cm tall turf plug remover five cm into the turf. When the turf plug remover was removed from the turf,

the turf-soil core, 2.5 cm diameter X ten cm tall, was removed to a separate zip-lock plastic bag.

There were four sampling groups, 1) non-infected Midlawn, 2) non-infected Tifgreen, 3) SDS infected Midlawn, and 4) SDS infected Tifgreen. The plugs from non-infected Midlawn and Tifgreen were harvested from the non-inoculated portion of the turf plot well away from the previously inoculated locations. The plugs from SDS infected Midlawn and Tifgreen were harvested from the edge of what was the spring visible patch, on November 11, 2001.

Three 2.5 cm diameter X five cm deep cores were removed from each of the four treatment plots, packaged in plastic bags, placed on ice, and transported to the laboratory. Within an hour of collection, all plugs were gently washed with sterile Nanopure water to remove soil and dead sheaths from the crown tissue and rhizomes. During processing, the shoots and roots were removed, and the crown tissue and rhizomes were pooled and mixed into one sample for each treatment. When processing was completed, each of the four pooled and mixed treatments, Midlawn non-infected, Midlawn infected, Tifgreen non-infected, and Tifgreen infected, were divided into three replicates each for a total of 12 samples (Table 14). Each replicate was rinsed again in Nanopure water, blotted dry with a paper towel, weighed, and placed into individual 125 mL Erlenmeyer flasks for surface sterilization.

Surface Sterilization

All procedures were performed in a laminar flow hood using aseptic techniques. Nanopure water was filter-sterilized, then autoclaved, to eliminate extraneous bacteria. Glassware, growth media, glass beads, toothpicks, and all other implements were

sterilized prior to use. Procedures from collecting the bermudagrass plugs to plating the sterilized plant homogenate were conducted during the same day for all four treatments.

The tissue samples were pre-washed once in 125 mL Erlenmeyer flasks with 25 mL of sterile phosphate buffered saline (PBS) (McClung et al. 1983a; Barraquio et al. 1997). The PBS was decanted from the flasks and fresh PBS with 0.05% Tween 20 and 5.0 g of 2.5 mm glass beads (Barraquio et al. 1997) were added to the flask. The flasks were placed on a shaker table at 150 rpm for 30 minutes at room temperature. The liquid was decanted and the plant material was washed twice with sterile PBS to remove the detergent. The plant material was separated from the glass beads and transferred to another 125 mL flask with 50 mL of 70 % EtOH (McClung et al. 1983a). The flasks were placed on a shaker table at 100 rpm for 20 min. The 70 % EtOH solution was then removed and the plant material was rinsed twice with Nanopure water. Fifty mL of full strength commercial 6 % sodium hypochlorite bleach (Sturz et al. 1998) containing 0.05 % Tween 20 was added to the plant material in the flask. The flasks were placed on a shaker table at 100 rpm for 20 min. The bleach-Tween 20 solution was removed and the plant material was rinsed five times with Nanopure water, and immediately checked for culturable surface bacteria as described below.

Sterility Control Plates

Three rhizome/crown tissue samples per replicate were removed from the Erlenmeyer flasks, blotted and rolled onto the surface of tryptic soy agar (TSA) (Fluka 22092 tryptic soy broth or Becton Dickinson trypticase soy broth, St. Louis, MO) plates, one plate per replicate. Plant materials were returned to the same Erlenmeyer flasks. The sterility control plates were sealed with two layers of Parafilm®, wrapped in aluminum

foil to replicate the below ground environment, and incubated upside down at room temperature. Plates were inspected daily for bacterial growth for 10 days. Only two of 12 sterility control plates yielded bacterial growth: Midlawn non-infected replicate three and Tifgreen infected replicate two sterility control plates produced one bacterial colony each indicating surface sterilization was extensive but not complete. As a result, all plates streaked with plant homogenates for Tifgreen infected replicate two and Midlawn non-infected replicate three were discarded.

Isolation of Culturable Endophytic Bacteria

All inoculated agar plates were sealed with two layers of Parafilm®, wrapped in aluminum foil, and incubated upside down at room temperature. The plates were checked daily for bacterial growth. The surface sterilized plant material was homogenized separately for each replicate in a Waring blender with 70 mL of PBS for 1 min. Serial dilutions of 0.5, 10^{-1}, and 10^{-2} were made and 100 µL of each were spread with a glass rod dipped in 70 % EtOH, flamed, and cooled, on three 1 X media: TSA (Gardner et al. 1982; Shishido et al. 1995), potato dextrose agar (PDA) (Sigma, St. Louis, MO) and nutrient agar (NA) (Becton Dickinson, Cockeysville, MD) plates. These agar plates are referred to as spread plates. Bacterial growth was noted 3 to 7 days after inoculation on most spread plates, although some did not develop any colonies even after 10 days. All visible colonies were picked from the spread plates. A total of 1466 visible colonies were removed using sterile toothpicks, removing either the entire colony or portions of each colony (Table 15). Each picked colony was then placed into individual 1.7 mL microcentrifuge tubes containing one mL of liquid broth corresponding to the single medium used for the spread plates. These tubes were placed into cardboard boxes,

approximately 15 cm square X four cm tall, with microcentrifuge tube dividers. The lids were placed onto the box to mimic the underground environment, and the box was incubated at room temperature until visible growth of bacteria was evident, approximately two days.

To produce pure cultures, a subset totaling 130 colonies was randomly picked from 4 treatments (Table 15). The initial bacterial liquid cultures, see above paragraph, were serially streaked three times for isolation onto the same agar medium as the liquid medium. Some serially streaked plates developed colonies with two or more different morphologies. These colonies were picked and assigned an alpha-numeric identification number to associate it with its parent colony and were streaked three times in successive agar plates to produce pure cultures. A total of 89 colonies were produced from streaking the 130 original colonies for pure cultures. These 89 colonies were added to the 130 original colonies bringing the total to 219 pure cultures. These 219 cultures were individually used to inoculate individual 1.7 mL microcentrifuge tubes with one mL of nutrient broth, incubated for approximately two days, and stored for later use (Table 15).

Extraction of DNA from Bacterial Cultures

For each of the 219 endophytes replicate extractions were performed. Five mL of each pure endophyte culture were inoculated into 50 mL tubes containing five mL of tryptic soy broth. The test tube was incubated at room temperature on a shaker table at 65 rpm. After one to five days, when bacterial growth was evident, two aliquots of 1.5 mL were removed from each test tube, placed into separate 1.7 mL microcentrifuge tubes, and centrifuged at 6000 g for one min. After discarding the supernatant, the pellet was resuspended in 1.5 mL of PBS, centrifuged at 6000 g for one min and then the

supernatant was discarded. This wash step was repeated three times. After discarding the supernatants, the pellet was washed in one mL of 1 M NaCl and centrifuged at 6000 g for one min. The supernatant was discarded and the pellet was resuspended in 100 μL of Nanopure water. The two resuspended replicate pellets for each isolate were combined into one 1.7 mL microcentrifuge tube and stored on ice for the next step. The combined pellet suspension of 70 μL was removed to a 2 mL boiling tube, a screw-capped tube with rubber O-ring in cap (United Scientific Products, San Leandro, CA), with 1.0 mg of 0.10 mm glass beads (Biospec Products, Inc., Bartlesville, OK). The boiling tube was shaken for 1 min at 1400 rpm in the bead beater (Biospec Products, Inc., Bartlesville, OK) then placed on ice. The boiling tube was centrifuged at 6000 g for one min and the supernatant containing the isolated DNA was removed to a fresh 1.7 mL microcentrifuge tube and stored at –20 °C.

PCR Amplification, PCR Product Cleanup, and 16S rDNA Sequencing

The 16S rDNA of the 219 culturable bacteria was amplified using the Qiagen Taq DNA Polymerase according to manufacturer's instructions (Qiagen, Valencia, CA). PCR primers were synthesized by Integrated DNA Technologies (Coralville, ID). The PCR master mix consisted of: Qiagen Buffer (1X), $MgCl_2$ (3 mM), dNTP (0.2 mM each), forward primer 5'-CAG CAG CCG CGG TAA TA-3'(250 nM), reverse primer 5'-CAA CAT CTC ACG ACA CGA GC-3' (250 nM), and Taq DNA polymerase (1U/100 μL). The PCR reaction was run in a MJ PTC-200 (MJ Research, Watertown MA) thermal cycler with a program as follows: initial denaturation at 94 ˚C for three min, cycle denaturation at 94 ˚ C for one min, cycle annealing at 52 ˚C for 30 sec, cycle extension at 72 ^{o} C for one min, repeat cycle steps 34 more times, final extension 72 ˚ C for ten min,

and then hold at 4 ˚ C. The tubes were placed in the thermal cycler at 94 ° C to "Hot Start" the reaction.

The PCR amplifications were checked by gel electrophoresis using a 2 % agarose gel, 0.5 X tris-borate EDTA buffer for running buffer, and six µL of PCR product (Sambrook and Russell 2001). The electrophoresis was conducted at 8 V/cm, at room temperature, until the tracking dye migrated approximately 3/4 the length of the gel. The DNA bands were photographed under long wave ultraviolet light using a Bio-Rad Gel Doc system (Bio-Rad Laboratories, Hercules, CA).

The unused primer and dNTPs were removed from the PCR products using a 96 well MultiScreen HV plate (Millipore Corp., Billerica, MA) loaded with hydrated Sephadex G-50 beads (Amersham Pharmacia, Piscataway, NY). A maximum of 20 µL of PCR product was added to the center of each well and centrifuged at 3000 g at room temperature for 5 min into a collection plate. The filtrates in the collection plate contained the purified PCR product for sequencing. The collection plate was covered with plastic adhesive backed tape and stored at –20 ˚C until sequencing. The DNA sequencing was performed at the Recombinant DNA/Protein Core Facility, Oklahoma State University, Stillwater, OK.

DNA Sequence Analysis

The 219 bacterial endophyte DNA sequences were trimmed of uncertain bases and vector sequences (N) at the 5' and 3' ends generating sequences between 483 and 963 bases long. Fifty endophyte sequences of low quality (greater than 1.0 % N, fewer than 500 bases) were discarded, leaving 169 high quality DNA sequences from the 219 bacteria (Table 15).

Endophyte Putative Identification

Endophyte DNA sequences were compared to known 16S ribosomal sequences using BLAST (Altschul et al. 1997) algorithms from the nonredundant nucleotide sequences in the National Center for Biotechnology Information (NCBI) database. The search consisted of pairwise comparisons using the low complexity filter for bacteria only and the 10 best matches were selected. Putative identifications of endophyte taxa were made using several scenarios **(**Table 16).

Alignment of the 16S rDNA Contig Sequence using ClustalX 1.8

All 16S rDNA sequences were aligned using ClustalX 1.8 software for Macintosh computers (Thompson et al. 1997). The parameters for the pairwise alignment were set by selecting 10.0 for gap opening, 0.1 for gap extension, and IUB for the DNA Weight Matrix. Hall's (2001) suggestion to set the pairwise alignment and multiple alignment parameters to the same settings even though only one of the two alignments were to be selected was followed. The parameters for the multiple alignment were 10.0 for gap opening, 0.1 for gap extension, 30 for delay divergent sequences (%), 0.50 for DNA transition weight [0-1], use negative matrix, and select IUB for DNA weight matrix.

De-Replication of Endophytic Bacteria Putatively Identified as *Microbacterium*

By far the most abundant genus found was *Microbacterium* (Orla-Jensen 1919) Takeuchi & Hatano 1998, comprising 71 isolates out of the 169 sequences representing 42% of all isolates (Table 15). Seventy-one putatively identified *Microbacterium* 16S rDNA contig sequences were aligned using ClustalX 1.8 to determine if the clones had identical sequences (Table 15). The alignment included the 71 *Microbacterium*, the *Escherichia coli* (Migula 1895) Castellani & Chalmers 1919, and the *E. coli* 0157:H7

16S rDNA gene sequence to act as a guide in truncating the aligned sequences to homologous regions in the 16S gene. The aligned sequences were truncated at the 5' end at nucleotide number 534, and at the 3' end at nucleotide number 1019 of the *E. coli* 0157:H7 gene sequence. The alignment produced 5 sets of putative clonally derived 16S rDNA contig sequences and one set of 25 distinguishable 16S rDNA contig sequences. One contig sequence from each of the 5 sets of indistinguishable sequences was randomly selected and added to the 25 distinguishable sequences to yield 30 unique *Microbacterium* 16S rDNA contig sequences **(**Table 15). This reduction of 41 *Microbacterium* sequences resulted in a total of 128 unique culturable bacterial endophyte sequences for analysis.

Cladogram of 128 Endophytic Bacterial Isolates, *Bacillus megaterium*, and *E. coli* 0157:H7

An alignment of 16S rDNA contig sequences from 128 endophytic bacterial isolates was performed **(**Table 15). Database 16S rDNA sequences from *B. megaterium* de Bary 1884 (AY030338 (Venkateswaran et al. 2003)) and *E. coli* 0157:H7 (NCBI accession number AY513502 (Gee et al. 2004)) were included in the alignment as representatives of Gram-positive and Gram-negative bacteria. The aligned sequences were truncated at the 5' end corresponding to *E. coli* 0157:H7 16S rDNA nucleotide number 465 and at the 3' end corresponding to nucleotide number 1041.

All cladograms were neighbor-joining bootstrapped (1000 X). Phylip software version 3.573c (Felsenstein 1989) was used to generate the neighbor-joining bootstrapped tree. TreeView PPC 1.6.6 software (Development) (Page 1996) was used to view the tree. For all cladograms, branches with bootstrap values less than or equal to 500 were

collapsed. A neighbor-joining bootstrapped (1000 X) cladogram was constructed, as mentioned earlier, from the truncated alignment and the internal branches were labeled to class using the putative identifications of the endophytic bacteria. The cladogram was divided into clades by dissecting the classes. One endophyte representative was randomly chosen from each homogeneous clade of the neighbor-joining bootstrapped (1000 X) cladogram of the 128 isolates. In the case of heterogeneous clades one member of each taxon was randomly chosen as collective representatives of that clade.

The Selection of Type Species from the NCBI Database

The web-based List of Bacterial Names with Standing in Nomenclature (http://www.bacterio.cict.fr) was searched for the type species of each putatively identified genus and for the strain identification numbers, e. g. American Type Culture Collection (ATCC) (www.atcc.org). The NCBI database was searched to find the 16S rDNA sequences of the type species. All but two clade representative endophytic bacteria, *Afipia* Brenner et al. 1992 emend. La Scola et al. 2002 and *Mycobacterium* Lehmann & Neumann 1896, had their type species 16S rDNA gene in the NCBI database. The type species for *Afipia* is *A. felis* Brenner et al. 1992 (ATCC53690). There are several *A. felis* strains with 16S rDNA genes partially sequenced and the longest available sequence (NCBI accession number AF338177 (van Berkum and Eardly 2002), ATCC49715) was chosen. The type species of *Mycobacterium* is *M. tuberculosis* (Zopf 1883) Lehmann & Neumann 1896 (ATCC27294). *M. tuberculosis* strain H37/Rv (NCBI accession number X55588 (Wolters 1990) is a member of the type species. Its genome is completely sequenced and the 16S rDNA sequence from this strain was used.

Alignment of the 16S rDNA Contig Sequences

The 16S rDNA sequences for 25 endophyte representatives, 17 type species references, Afipia (A338177), Mycobacterium (X55588), and *B. megaterium* were aligned using Clustal X 1.8. The alignment was truncated to yield a fragment from nucleotides 570 to 1218 according to the *B. megaterium* 16S rDNA sequence. A neighbor-joining bootstrapped (1000 X) cladogram was generated from the truncated alignment of the 45 16S rDNA contig sequences using the aforementioned parameters.

O. herpotricha Antagonism Assay

O. herpotricha KS strain 188 was acquired from Ned Tisserat of Colorado State University and maintained on autoclaved oats (Ag Center, Stillwater, OK). The autoclaved oats were prepared in one liter glass jars with screw-lids filled half way with whole oats and 250 mL of Nanopure water. The jars were autoclaved then cooled. One jar of autoclaved oats was inoculated with one 1 cm diameter plug of *O. herpotricha* hyphae and agar removed from the leading edge of actively growing hyphae on PDA.

The assay to measure the antagonism of culturable endophytic bacteria to *O. herpotricha* was performed in duplicate on 6 different media, 1/5X and 1X NA, PDA, and TSA, to determine if *in vitro* antagonism is nutrient dependent. A 1 cm diameter plug of *O. herpotricha* hyphae and agar was removed from the actively growing leading edge of the *O. herpotricha* fungus on PDA. The plug was placed onto the center of 150 mm diameter medium plates, one per plate. The plates were ready for bacterial inoculation when the hyphae grew half the distance to the edge of the plate. Each plate was marked to delineate 16 equal wedges and two µL of each of 16 pure endophyte cultures grown in tryptic soy broth were inoculated onto the surface of the agar two mm

from the leading edge of the fungus. The drops were allowed to dry in the covered plate inside the laminar flow hood. Antagonism was assessed after the fungus grew beyond and between the bacterial colonies.

Antagonism was measured by assigning a numerical score. A score of zero indicated no antagonism; the fungus grew all the way through the bacterial culture with visible hyphae extending beyond the bacterial culture in the agar. A score of one indicated a slight retardation in the leading edge of hyphae: the fungus grew through the bacterial colony, but did not extend beyond the bacterial colony. Score of two indicated the leading edge of the fungus grew two thirds of the distance through the bacterial colonies. Three indicated the leading edge grew one third of the distance through the bacterial culture. Four indicated the leading edge touched the edge of the bacterial colony but did not grow into the colony. Five indicated a zone with no fungal or bacterial growth between the leading edge of the fungus and the edge of the bacterial colony.

RESULTS

The first phase of this study compared bacterial endophyte diversity in two bermudagrass cultivars, SDS resistant Midlawn and susceptible Tifgreen. The four treatments were *O. herpotricha* infected and non-infected Midlawn and Tifgreen plants. A total of 1466 isolates encompassing all treatments (Table 14) were recovered from our samples. Non-infected Midlawn plants generated the greatest number of culturable bacterial endophytes whereas the least number was isolated from infected Tifgreen followed closely by infected Midlawn (Table 15). One replicate from Midlawn non-

infected plants stood out among all agar plates, as it yielded the greatest number of endophyte colonies (Table 14). The geometric mean of replicate measurements of culturable bacterial counts ($\log_{10}$ CFU g^{-1}) per treatment were Midlawn non-infected, 5.2; Midlawn infected, 5.1; Tifgreen non-infected, 5.0; and Tifgreen infected, 4.5.

To study the endophyte taxa richness in the four treatments, we originally aimed to select 50 isolates per treatment. However, two treatments, infected Midlawn and Tifgreen, gave fewer than 50 colonies from all plates combined. In addition, owing to an oversight, fewer colonies were selected from some treatments than planned (Table 15). When the selected colonies were triple-streak purified additional bacterial isolates were present. The final total of 128 culturable bacterial endophytes were distributed as follows: Midlawn non-infected with 32 isolates, Midlawn infected with 19 isolates, Tifgreen non-infected with 50 isolates, and Tifgreen infected with 27 isolates (Table 15).

The 128 culturable bacterial endophytes were putatively classified by matching their 16S rDNA c sequence against the NCBI database using the BLAST algorithymn. In addition, the 128 bacterial endophytes were assigned to major categories, groups, phyla, classes, and genera as described in Bergey's Manual of Systematic Bacteriology 9th edition (Holt et al. 1994) using the guidelines listed in Table 16. Of the 128 endophytes, 77 belonged to Major Category I, the gram-negative rods and cocci with cell walls, and 51 endophytes belonged to Major Category II, the gram-positive rods and cocci with cell walls (Table 17). The Major Category I contained 11 putatively identified genera. The most frequently isolated Major Category I genus was *Acidovorax,* followed by *Stenotrophomonas* and *Pseudomonas*. The genera with the fewest members were *Sphingomonas*, *Pantoea*, and *Rhizobium* (Table 17). The Major Category II contained 7

genera with *Microbacterium* and *Curtobacterium* the most frequently isolated genera. The genera with the fewest numbers were *Amycolatopsis*, *Geodermatophilus*, *Mycobacterium*, and *Staphylococcus*.

Assessing the diversity of endophyte taxa of the four treatments was an integral part of this experiment because the difference in genera richness may be cultivar and disease dependent. Eighteen genera and six broad taxa were isolated from the four treatments. Broad taxa of class, family, or group were assigned to those isolates whose genus classification was uncertain. There was a positive relationship between the number of CFUs in each treatment and the number of different taxa in each treatment (R^2=0.78). Non-infected plants displayed a greater diversity of genera and CFUs than diseased plants. Fourteen genera and five broad taxa were isolated from non-infected Midlawn and Tifgreen plants and 11 genera and three broad taxa were isolated from the infected plants (Table 18). Susceptible Tifgreen displayed a greater diversity of genera and CFUs than resistant Midlawn (Table 18). Sixteen genera and six broad taxa were isolated from non-infected and infected Tifgreen plants and nine genera and three broad taxa were isolated from non-infected and infected Midlawn plants. Only one genus, *Microbacterium*, was isolated from all 4 treatments.

The similarities of the 128 16S rDNA endophyte sequences were assessed by using ClustalX 1.8 software to align these sequences including the 16S rDNA reference sequences from *B. megaterium* and *E. coli*. A neighbor-joining bootstrapped (1000 X) cladogram was constructed and the algorithm grouped the endophyte sequences into the classes *Actinobacteria*, "*Bacilli*", "*Flavobacteria", "Alphaproteobacteria",* "*Betaproteobacteria*", and "*Gammaproteobacteria*" (Figs 1-5). The class *Actinobacteria*

was divided into the most clades and contained the largest number bacterial endophyte isolates (Figs. 1, 4 and 5). The class with the fewest isolates and thus smallest clade was the "*Flavobacteria*" clade (Figs. 1, 4). Of the *Proteobacteria* classes, "*Gammaproteobacteria*" was divided into two separate clades and contained the greatest number of bacterial isolates followed by the separate clades of "*Alphaproteobacteria*" and "*Betaproteobacteria*" (Figs. 2, 3).

A second neighbor-joining bootstrapped (1000 X) cladogram was constructed with the 16S rDNA sequences of clade representative endophytes and their type species or closely related strains to demonstrate how representative sequences would group with known taxa (Fig. 6). The neighbor-joining algorithm paired 11 endophyte representatives with their type species (Fig. 6). However, 8 of the putatively identified endophytes did not directly pair with known taxa.

The *in vitro* antagonism of 219 culturable bacterial endophytes towards *O. herpotricha* was assayed to assess their potential as antifungal isolates with promising biological control properties. Experiments were conducted to determine the level of endophyte antagonism against *O. herpotricha* in three different laboratory media, NA, PDA, and TSA at two concentrations 1X and $1/5^{th}$ to determine if *in vitro* antifungal properties were nutrient dependent. *O. herpotricha* hyphal growth was visually measured and grew equally well on 1 X NA, PDA, and TSA media and had a reduced growth rate on the $1/5^{th}$ NA, PDA, and TSA media. Thirty-one putatively identified bacterial endophytes were antagonistic *in vitro* towards the causal agent of SDS, *O. herpotricha*. These bacterial endophytes displayed different levels of antagonism on different media. In general, full strength media (1 X) supported greater levels of antifungal properties than

the 1/5th media (Table 19). There was a greater number of antifungal isolates from non-infected Midlawn and Tifgreen plants compared to infected Midlawn and Tifgreen plants. The number of isolates from non-infected Midlawn compared to non-infected Tifgreen plants was similar as was the number of isolates from infected Midlawn compared to infected Tifgreen plants. None of the antagonistic endophytes were isolated from all four treatments, nor were all members of any taxon antifungal (Table 20). The 31 antifungal isolates were grouped by the neighbor joining algorithm into the classes *Actinobacteria*, *"Bacilli"*, *"Betaproteobacteria"*, *"Gammaproteobacteria"*, and *"Flavobacteria"* with the two "*Gammaproteobacteria*" clades containing the highest numbers of isolates (Figs. 2-5).

DISCUSSION

Spring dead spot produces circular patches of dead and dying bermudagrass that are visible in the spring. Over the summer, the patches disappear as the bermudagrass re-colonizes the infection zone. When lower autumn temperature arrive, bermudagrass enters dormancy and presumably infection occurs (Fermanian et al. 2003). It was during this transition time in late autumn that samples were harvested for this endophyte study. Non-infected plant material showed no signs of necrosis. In infected material only a small percentage, approximately 10 - 20 %, of the underground structures of infected plants of both cultivars had visible black plaques and necrosis. This infrequent occurrence of visible necrosis may be characteristic of a patchy distribution of infection within the root system of infected bermudagrass. So far very little research, if any, has been conducted on SDS distribution in the infection zone within the field. If SDS is

patchy distributed then many more samples should be taken to quantify the level of infection in terms of the frequency of infected tissues compared to non-infected tissues. If this study was to be repeated in the field we would increase the number of samples. We hypothesize that this would provide an adequate comparison among treatments as to the degree of infection. Much more research is necessary on the environmental conditions and the temporal and spatial distribution of infection of SDS causing organisms in the field before an adequate understanding of the disease can be obtained. We have initiated a study to determine the distribution of *O. herpotricha* in patches of dead and dying turf during the spring (Chapter 2 of this thesis); the results generally support the idea of a patchy distribution.

Culturable Bacterial Endophytes

This study is the first to document the diversity of culturable bacterial endophytes from surface sterilized crown tissues of bermudagrass cultivars. In addition, this study presents an original comparison of the diversity of culturable bacterial endophytes in plants infected with the causal agent of SDS, the fungus *O. herpotricha,* and non-infected plants. We focused on the endophytes associated with the crown tissue because the crown tissue is the perreniating tissue for root and shoot initiation and may serve as the distribution point for some of the endophytes found in roots and shoots. Endophytes from other plant species have been shown to migrate into either root (Marti et al. 1999) or shoot tissues (Patriquin et al. 1978; Gardner et al. 1972; Gagné 1987) from the crown.

Abundance of Culturable Bacterial Colonies

There was a high disparity among the number of visible colonies on agar plates spread with serial dilutions of the plant homogenate from different treatments. Infected Midlawn, non-infected Tifgreen, and infected Tifgreen serially diluted plant homogenates produced a total of 36, 124, and 35 visible colonies, respectively (Table 14). In contrast, Midlawn non-infected serial diluted plant homogenate produced the highest number of visible colonies for a total of 1271, with Midlawn replicate 1 contributing 1249 colonies and replicate 2 with 10 colonies and replicate 3 contributed 12 colonies but was discarded because the corresponding sterility control plates were contaminated. The anomalous high number of visible colonies obtained from Midlawn non-infected replicate 1 is at least 20-fold higher than any other replicate, and could be attributed to heterogeneous distribution of endophytes in the harvested plant tissues. The material extracted from homogenized material from replicate 1 probably contained far greater densities of endophytes than all other plant tissue replicates. The differences in colony counts cannot be attributed to variations in the mass of plant tissue as replicate 2 from the same pooled plant material yielded vastly fewer colonies (9 vs. 1029) than replicate 1 (Table 14). Such wide variations in endophyte abundances from replicate samples are common, with some reports demonstrating variations covering 4-6 orders of magnitude (Zinniel et al. 2002; Bell et al. 1995). The reasons underlying such heterogeneity remain to be more fully explored.

Community Ecology of Culturable Bacterial Endophytes

The putatively identified culturable bacterial endophytes isolated in this study are distributed across Major Category I, the gram-negative rods and cocci with cell walls and

Major Category II, the gram-positive rods and cocci with cell walls as described in Bergey's Manual of Systematic Bacteriology 9th edition (Holt et al. 1994) (Table 17). The 128 bacterial endophytes whose 16S rDNA sequences displayed a positive relationship between the number of CFUs recovered from each treatment and the number of different taxa documented in each treatment (R^2=0.78). In other words, those treatments with the higher numbers of culturable CFUs were richer in diversity of endophyte genera.

For the most part, the 18 genera and 6 broad taxa, e. g. *Enterobacter* Hormaeche & Edwards 1969/*Pantoea* Gavini et al. 1989 emend. Mergaret et al. 1993 and *Microbacteriaceae* Park et al. 1995, fall in the range of plant endophytes isolated and identified from various agricultural crops (McInroy and Kloepper 1995b; Sturz et al. 1997; Garbeva et al. 2001) (Table 19). However, there were exceptions to this rule. Some bacteria known to inhabit soils but not plants were identified as bermudagrass endophytes in this study. To our knowledge, this is the first report of endophytes from genera *Amycolatopsis* Lecheralier et al. 1986 and *Geodermatophilus* Luedemann 1968 from any plant species. Both genera are classified under the order *Actinomycetales* Buchanan, 1917. *Amycolatopsis* has been isolated from soils in China, India, Brazil, and Kuwait (Chung et al. 1999; Wink et al. 2003; Semedo et al. 2001; Al-Musallam et al. 2003). Of special interest, *Amycolatopsis* has been shown to produce several antibiotics including the commercial antibiotics vancomycin and rafamycin (Jin et al. 2002; Padma et al. 2002; Krishna et al. 2003; Wink et al. 2003). The genus *Geodermatophilus* contains one described species, *G. obscurus* (Luedemann, 1968). *Geodermatophilus* has been isolated from diverse environments including soils of the Mojave Desert

(California-Nevada, USA), Asgard Range (Transantarctic mountains), and Gardabani raion (sic) (Central Georgia in Asia) (Garrity et al. 1996; Mevs et al. 2000; Kudukhashvili et al. 2001; Dungan et al. 2003). *G. obscurus evereste* has been touted as the highest living bacterium on earth (Moffat, 2004) but this bacterium subspecies name (*evereste*) has no standing in bacterial nomenclature and is found neither in the NCBI database nor the American Type Culture Collection.

The most abundant endophytes in the crown tissue, in terms of number of colonies recovered, belong to the genus *Microbacterium*. This genus was unevenly distributed among 4 treatments. The reasons underlying the reduced number of *Microbacterium* isolates in diseased Midlawn crown tissue are not known. The unique environment associated with diseased Midlawn tissues may have influenced *Microbacterium* growth. Even so, *Microbacterium* is ubiquitous in plants and has been documented in surface sterilized leaves, stems, and roots of several agronomic crops, grasses, and prairie plants as well as soils (McInroy and Kloepper 1995a; Elbeltagy et al. 2000; Chelius and Triplett 2001; Garbeva et al. 2001; Zinniel et al. 2002; Mostafa and Helling 2003; Macur et al. 2004; Zhang et al. 2004). The unfastidious habit of *Microbacterium* may be attributed to its metabolism, which is primarily respiratory but can be weakly fermentative and chemoorganotrophic (Holt et al. 1994).

Comparison of Resistant and Susceptible Cultivars

Midlawn and Tifgreen are resistant and susceptible hybrids, respectively, of *Cynodon dactylon* (L.) Pers. One aim of this investigation has been to determine whether resistant and susceptible cultivars sustain different endophyte communities. The ratio of identified taxa to the number of isolated endophytes was similar in healthy Midlawn and

Tifgreen crown tissues, 0.31 and 0.34 respectively. This measure of endophyte diversity suggests that the diversity and abundance of bacterial endophytes were similar in these resistant and susceptible cultivars. Our findings of no cultivar dependence of endophyte diversity coincide with those of Sturz et al. (1999), who studied 4 potato (*Solanum tuberosum* L.) cultivars and Adams and Kloepper (2002) who investigated 9 cotton (*Gossypium hirsutum* L.) cultivars. In contrast, cultivar differences were found in the works of Sturz and Christie (1999) who studied 4 red clover (*Trifolium pratense* L.) cultivars, and Germida and Siciliano (2001), who compared ancient land races and recent cultivars of rice (*Oryza*).

Endophyte Diversity in Healthy and Diseased Plants

One goal of this study was to determine the impact of disease on the abundance of bacterial endophytes. SDS was not associated with marked effects on the abundance (5.1 vs. 5.2 $\log_{10}$CFU g^{-1}) of bacterial endophytes in infected Midlawn plants compared to non-infected plants, respectively. However, the endophyte abundance in Tifgreen plants exhibited more substantial differences when comparing healthy with diseased plants. Endophyte abundance was lower in infected Tifgreen plants compared to non-infected plants, 4.5 vs. 5.0 $\log_{10}$CFU g^{-1}, respectively.

In vitro Antagonism of Endophytes Towards *O. herpotricha*

There are numerous studies characterizing culturable bacterial endophytes with respect to activity against phytopathogenic organisms (Tervet and Hollis 1948; Knutson 1973; McClung et al. 1983a; Barraquio et al. 1997; Araújo et al. 2002). To our knowledge, our study is the only one that compares the genera richness, abundance, and

antifungal properties of culturable bacterial endophytes between resistant and susceptible cultivars and in healthy and diseased plants.

In vitro antifungal properties of 128 bacterial endophytes were assayed to determine if Midlawn or Tifgreen differed in taxa and abundance of antagonist endophytes. We also wanted to discover and identify suitable endophytes to develop into a biological control agent for SDS. Ten endophyte taxa displayed significant *in vitro* antagonism towards *O. herpotricha* (Table 20). A comparison of their antagonism with that of known antifungal bacteria reveals a precedent that certain members of these taxa show significant antifungal properties (Table 21). To our knowledge, we are the first to document the *in vitro* antifungal properties of a *Chryseobacterium* sp. The genus *Chryseobacterium* was described in 1994 by Vandamme et al. and includes some members formerly classified in the genus *Flavobacterium* Bergey et al. 1923. *Chryseobacterium* has been isolated from soils (Radianingtyas et al. 2003; Rosado and Govind 2003; Wery et al. 2003) and natural waters (Arvanitidou et al. 2003). A few *Chryseobacterium* spp. are opportunistic pathogens in humans with compromised immune systems (Bloch et al. 1997; Fraser and Jorjensen 1997).

Non-infected Midlawn and Tifgreen plants contained 87 % of the *in vitro* antagonistic CFUs while 13% of the antagonistic CFUs originated from infected plants (Table 16). Some of this difference can be attributed to the distribution of the 128 isolates among the 4 treatments, with 64% coming from non-infected plants and 36% from infected plants (Table 18). Furthermore, 10 of the 46 isolates from infected plants were identified as *Acidovorax*, and none of the *Acidovorax* isolates showed any antagonism toward *O. herpotricha* (Tables 18 and 20). Both antagonistic and non-

antagonistic members were found within 9 of the 10 taxa containing antagonistic bacteria. Exceptions were the two *Xanthomonadaceae*; both of which displayed *in vitro* antagonism towards *O. herpotricha*. Sturz et al. (1998) reported similar findings of antagonistic and non-antagonistic members within endophyte species: 1 of 2 *Bacillus brevis* Migula 1900 isolates and 2 of 7 *Pseudomonas chichorii* (Swingle 1925) Stapp 1928 displayed *in vitro* antagonism towards *Rhizoctonia solani* Kuhn.

The *in vitro* antagonism of the antifungal bacterial endophytes in this study might be attributed to competition for nutrients between *O. herpotricha* and the individual bacterium. This kind of *in vitro* assay does not distinguish effects of nutrient depletion from production of antimicrobial metabolites. Growth medium influenced the level of *in vitro* antagonism with 1 X TSA sustaining the greatest and 20 % NA the least antagonism, as a rule, over all isolates tested (Table 19). This suggests the nutritional environment is important for the expression of antagonism (James and Gutterson 1986; Milner et al. 1996; Duffy and Defago 1999). The nature of the nutritional environment and effect of nutrient composition on endophytic growth in the bermudagrass apoplastic space are yet to be determined. Studies characterizing the bacterial endophyte antagonism towards *O. herpotricha* using natural apoplastic fluids may lead to a greater understanding of the effect of nutrients under conditions that better simulate the natural apoplast environment.

The antifungal culturable bacterial endophytes from this study have potential as biological control agents against *O. herpotricha*. There are precedents for use of bacteria as successful biological control agents for plant diseases; some examples of such commercial products include: Companion (*Bacillus subtilis* (Ehrenberg 1835) Cohn

1872 GB03, Growth Products, White Plains, NY), Subtilex (*B. subtilis*, The MicroBio Group Ltd., Boulder, CO), Spot-Less (*Pseudomonas aureofaciens* Kluyver 1956 TX-1, Eco Soil Systems, Inc., San Diego, CA) (Fravel 2000), and Serenade (*B. subtilis* QST-713, AgraQuest Inc., Davis, CA), the later of which possesses broad range fungicidal activity (Ritter 2003). In our study, we have isolated antifungal members of the genera *Bacillus* Cohn 1872 and *Pseudomonas* Migula 1894, two of the genera most used for biological control purposes. Additional research is ongoing to establish whether one, or a collection, of our antifungal bacterial endophytes could be developed into a biological control agent for *O. herpotricha*.

Bacterial Endophytes as Biological Control Agents

The development of bacterial endophyte(s) into biological control agent(s) for soil fungal phytopathogens poses a challenge. There are distinct advantages of employing the endophyte system for biocontrol purposes, even though few, if any, endophytes have been developed for this purpose. Endophytes are particularly well adapted to thrive within plant tissues, which might contribute to successful biocontrol. The antagonistic endophytic bacteria isolated in this study offer potential as biocontrol agents, but further research is necessary to optimize the colonization and antagonism of these endophytes.

CONCLUSIONS

Seventy-seven Gram-negative and 51 Gram-positive culturable bacterial endophytes, including some with *in vitro* antifungal attributes, were readily isolated from the crown tissue of resistant Midlawn and susceptible Tifgreen cultivars of bermudagrass, infected with *O. herpotricha* and non-infected. This study is the first, to our knowledge,

to document a *Geodermatophilus* sp. and an *Amycolatopsis* sp. as plant endophytes. The diversity of taxa and abundance of bacterial endophytes were similar in healthy and diseased Midlawn crown tissues. In Tifgreen, infected plants exhibited lower endophyte abundance but greater diversity of taxa compared to healthy plants. Antifungal endophytes were abundant in healthy Midlawn and Tifgreen plants, but their abundance was substantially lower in infected plants from both cultivars. We report the first observation, to our knowledge, of *in vitro* antifungal attributes of a *Chryseobacterium* sp.

There are several attributes required for a successful biological control agent for *O. herpotricha*. Ease of culture and long shelf-life are necessary for low-cost commercial production. Ease of inoculation, such as a root dip or application to the soil, makes the product user-friendly. The successful biocontrol agent must have fitness in the rhizosphere, motility to the root, and a method to enter the root. The biocontrol agent must also have fitness inside the root and the ability to display antagonism inside the root.

The abundance and diversity of culturable bacterial endophytes in bermudagrass demonstrate that turfgrasses are good hosts and valuable resources for endophytes with antifungal properties. The cohort of *in vitro* antifungal bacterial endophytes has potential as biological control agents for SDS. The culturable bacterial endophytes in our collection merit further study to elucidate the dynamics of their microbial communities, their classification, taxonomy, and physiological aspects conducive to biological control agents.

Table 14. Replicates, dilutions, and number of culturable bacterial endophyte colonies isolated from surface sterilized crown tissue from 4 experimental treatments of Midlawn and Tifgreen cultivars of bermudagrass. g of tissue = g of crown tissue and rhizomes

Cultivar	Midlawn	Non-infected							
Replication	1			2			3 DID	NOT	USE
g of tissue	0.25 g			0.26 g			0.27 g		
Dilution	0.5 X	10^{-1}	10^{-2}	0.5 X	10^{-1}	10^{-2}	0.5 X	10^{-1}	10^{-2}
Colonies	1029	212	16	9	1	0	3	1	0
Cultivar	Midlawn	Infected							
Replication	1			2			3		
g of tissue	0.15 g			0.15 g			0.14 g		
Dilution	0.5 X	10^{-1}	10^{-2}	0.5 X	10^{-1}	10^{-2}	0.5 X	10^{-1}	10^{-2}
Colonies	20	4	2	6	4	0	44	7	2
Cultivar	Tifgreen	Non-infected							
Replication	1			2			3		
g of tissue	0.37 g			0.40 g			0.44 g		
Dilution	0.5 X	10^{-1}	10^{-2}	0.5 X	10^{-1}	10^{-2}	0.5 X	10^{-1}	10^{-2}
Colonies	59	7	0	8	2	1	50	8	0
Cultivar	Tifgreen	Infected							
Replication	1			2 DID	NOT	USE	3		
g of tissue	0.38 g			0.42 g			0.42 g		
Dilution	0.5 X	10^{-1}	10^{-2}	0.5 X	10^{-1}	10^{-2}	0.5 X	10^{-1}	10^{-2}
Colonies	1	0	0	1	0	0	27	3	3

Table 15. The number of culturable bacterial endophytes isolated from the crown tissue of Midlawn and Tifgreen cultivars of bermudagrass. The protocol steps and the number of colonies per treatment at each step.

Protocol Step	Midlawn non-infected	Midlawn infected	Tifgreen non-infected	Tifgreen infected	TOTAL
1. Original colonies picked from spread plates.	1271	36	124	35	1466
2. Selected colonies for study from replicates and dilutions.	16	20	48	28	112
3. Add colonies to bring all treatments to 50 colonies. Did not add enough colonies to the study. An oversight.	17	0	0	1	18
4. The colony totals (add step 2 and step 3). These colonies were streaked thrice to obtain pure cultures.	33	20	48	29	130
5. The colony count after streaking thrice to obtain pure cultures.	50	34	87	48	219
6. Isolates with low quality DNA sequences.	10	8	20	12	50
7. Totals of high quality sequences. Subtracted the low quality DNA sequences from the pure cultures (subtract step 6 from step 5).	40	26	67	36	169
8. All *Microbacterium* sequences.	17	10	25	19	71
9. Clone *Microbacterium* sequences.	8	7	17	9	41
10. Totals of *Microbacterium* sequences. Subtracted the clone sequences from all the *Microbacterium* sequences (subtract step 9 from step 8).	9	3	8	10	30
11. Totals from subtracting the clone *Microbacterium* sequences from the high quality sequences (subtract step 9 from step 7).	32	19	50	27	128
12. The total number of isolates that were aligned and included in cladograms.	32	19	50	27	128

Table 16. Rules for selecting the BLAST identification for bacterial endophytes from 10 matches from the fungi database.

Rule 1: Remove all general or broadly named BLAST matches from consideration.

Rule 2: All BLAST matches used for identification will have a percent identity equal to or greater than 97 %.

Rule 3: Select the genus name of the first or first few BLAST matches when the bits scores are the highest of the matches.

Rule 4: Select the genera names of the first BLAST matches when their bits scores are the same, e. g. *Enterobacter/Pantoea*.

Rule 5: Select the family name of the genus or genera when the E-value is low and the percent identities are lower than 97 %.

Table 17. The culturable bacterial endophytes putative identification and classification as described in Bergey's Manual of Systematic Bacteriology 9th edition (Holt et al. 1994). The number of isolates (culturable bacterial endophytes) for each genera are in parenthesis.

Major Category I: Gram-negative eubacteria with cell walls.
- Group 4a: microaerophilic straight rods with strictly respiratory metabolism.
- Group 5.1: aerobic or facultatively anaerobic straight rods with chemoorganotrophism having respiratory and fermentative metabolism.

Phylum *Bacteriodetes*
- Class "*Flavobacteria*"
  - Genus *Chryseobacterium* (3 isolates)

Phylum *Proteobacteria*
- Class "*Alphaproteobacteria*"
  - Genus *Afipia* (Group 4a, 3 isolates)
  - Genus *Brevundimonas* (Group 4a, 6 isolates)
  - Genus *Rhizobium* (Group 4a, 2 isolates)
  - Genus *Sphingomonas* (Group 4a, 1 isolate)
- Class "*Betaproteobacteria*"
  - Genus *Acidovorax* (Group 4a, 12 isolates)
- Class "*Gammaproteobacteria*"
  - Genus *Pseudomonas* (Group 4a, 8 isolates)
  - Genus *Stenotrophomonas* (Group 4a, 11 isolates)
  - Genus *Xanthomonas* (Group 4a, 3 isolates)
  - Genus *Klebsiella* (Group 5.1, 5 isolates)
  - Genus *Pantoea* (Group 5.1, 2 isolates)
  - Informal group *Enterobacter/Pantoea* (Group 5.1, 7 isolates)

Major Category II: Gram-positive eubacteria with cell walls.
- Group 17: the cocci
- Group 18: the endospore-forming rods and cocci
- Group 20: the irregular nonsproing rods
- Group 21: the mycobacteria
- Group 22: norcardioform actinomycetes, morphologically and culturally similar to the genus *Nocardia*, a bacteria that forms mycelium that can fragment into rod or cocci shaped cells.
- Group 23: the actinomycetes with multicellular asexual spores in a multilocular sporangia, a spore case.

Phylum *Firmicutes*
- Class "*Bacilli*"
  - Genus *Staphylococcus* (Group 17, 2 isolates)
  - Genus *Bacillus* (Group 18, 3 isolates)

Phylum *Actinobacteria*

Class *Actinobacteria*

Genus *Microbacterium* (Group 20, 30 isolates)
Genus *Curtobacterium* (Group 20, 9 isolates)
Genus *Mycobacterium* (Group 21, 2 isolates)
Genus *Amycolatopsis* (Group 22, 2 isolates)
Genus *Geodermatophilus* (Group 23, 1 isolate)

Table 18. The CFUs and distribution of putatively identified culturable bacterial endophytes isolated from surface sterilized crown tissue from four treatments of bermudagrass cultivars, Midlawn and Tifgreen non-infected and Midlawn and Tifgreen infected with *O. herpotricha*.

Putatively Identified	Non-Infected		Infected	
Endophytes	Midlawn	Tifgreen	Midlawn	Tifgreen
Acidovorax	1	1	10	-
Afipia	1	1	-	1
Amycolatopsis	-	-	-	2
Bacillus	3	-	-	-
Brevundimonas	-	4	-	2
Chryseobacterium	2	1	-	-
Curtobacterium	1	7	-	1
Geodermatophilus	-	-	-	1
Klebsiella	5	-	-	-
Microbacterium	9	8	3	10
Mycobacterium	-	2	-	-
Pantoea	-	-	1	1
Pseudomonas	3	5	-	-
Rhizobium	-	1	-	1
Sphingomonas	-	1	-	-
Staphylococcus	-	-	-	2
Stenotrophomonas	5	5	-	1
Xanthomonas	-	3	-	-
Broad Taxa				
Enterobacter/Pantoea	2	5	-	-
Actinobacteria	-	-	-	1
"Alphaproteobacteria"	-	1	4	2
"Betaproteobacteria"	-	2	1	2
Microbacteriaceae	-	1	-	-
Xanthomonadaceae	-	2	-	-
Totals	32	50	19	27

Table 19. Culturable endophytic bacteria *in vitro* antagonism towards the fungal causal agent of Spring Dead Spot, *O. herpotricha*, in bermudagrass grown in different nutrient media. Antagonism was rated on a scale of 0-5 with 0 indicating no antagonism and 5 the highest. MN=Midlawn non-infected, TN=Tifgreen non-infected, MI=Midlawn infected with *O. herpotricha*, TI=Tifgreen infected with *O. herpotricha*, NA=Nutrient Agar, PDA=Potato Dextrose Agar, TSA=Tryptic Soy Agar.

Endophyte Number, Putative Identification	Treat-ment	1X NA	1/5XNA	1X PDA	1/5X PDA	1X TSA	1/5X TSA
219 *Bacillus*	MI	0	0	0	0	3	0
129 *"Betaproteobacteria"*	MI	0	0	0	0	3	0
36 *Chryseobacterium*	MN	0	0	0	0	3	2
20 *Enterobacter/Pantoea*	TN	2	0	1	0	3	1
22 *Enterobacter/Pantoea*	TN	3	0	1	1	3	0
24 *Enterobacter/Pantoea*	TN	1	0	1	1	3	0
37 *Enterobacter/Pantoea*	MN	1	0	1	0	3	1
44 *Enterobacter/Pantoea*	MN	1	0	0	0	4	0
215 *Klebsiella*	MN	3	0	1	0	2	0
78 *Microbacterium*	TN	1	2	0	0	4	2
60 *Pantoea*	TI	3	0	1	1	3	0
32 *Pseudomonas*	TN	1	0	4	0	4	3
33 *Pseudomonas*	MN	2	0	1	0	4	3
34 *Pseudomonas*	MN	1	0	4	0	4	3
35 *Pseudomonas*	MN	2	0	1	0	4	2
48 *Pseudomonas*	TN	2	2	3	0	4	3
52 *Pseudomonas*	TN	2	0	4	1	4	3
53 *Pseudomonas*	TN	2	0	1	0	4	3
38 *Stenotrophomonas*	MN	2	1	0	0	3	0
40 *Stenotrophomonas*	MN	2	2	4	0	4	4
41 *Stenotrophomonas*	MN	1	2	1	0	3	3
42 *Stenotrophomonas*	MN	2	2	0	0	3	1
46 *Stenotrophomonas*	TN	3	0	0	0	3	1
49 *Stenotrophomonas*	TN	2	1	1	0	3	2
51 *Stenotrophomonas*	TN	3	1	1	1	2	3
57 *Stenotrophomonas*	TN	2	0	0	0	3	1
59 *Stenotrophomonas*	TN	2	1	4	1	4	3
477 *Stenotrophomonas*	TI	0	3	0	0	3	3
50 *Xanthomonadaceae*	TN	2	1	1	1	3	0
67 *Xanthomonadaceae*	TN	3	2	0	0	3	0

Table 20. The CFUs of putatively identified culturable bacterial endophytes that displayed antagonism towards *O. herpotricha*. The antagonism ratings were numeric from 0-5, with 5 the highest antagonism response. None of the endophytes assayed displayed the highest rating of antagonism. Only those endophytes with moderate antagonism (3 to 4) are included. The CFUs are listed first followed by the antagonism rating(s) in parenthesis.

Putatively Identified Endophytes	Totals	Non-Infected Midlawn	Tifgreen	Infected Midlawn	Tifgreen
Bacillus	1	1 (3)	-	-	-
Chryseobacterium	1	1 (3)	-	-	-
Klebsiella	1	1 (3)	-	-	-
Microbacterium	1	-	1 (3)	-	-
Pantoea	1	-	-	-	1 (3)
Pseudomonas	7	3 (4, 4, 4,)	4 (4, 4, 4, 4)	-	-
Stenotrophomonas	10	4 (3, 3, 3, 4)	5 (3, 3, 3, 3, 4)	-	1 (3)
Broad Taxa					
Enterobacter/Pantoea	6	2 (3, 4)	3 (3, 3, 3)	1 (3)	-
"Betaproteobacteria"	1	-	-	1 (3)	-
Xanthomonadaceae	2	-	2 (3, 3)	-	-
Totals	31	12	15	2	2

Table 21. Species of culturable bacterial endophytes documented in other studies and isolated from the crown tissue of bermudagrass in this current study that possess antagonism towards the indicated plant pathogen.

Endophyte	Plant and Location	Pathogen	Reference
Bacillus pumilus strain 85	Corn kernel	*Rhizoctonia solani*	Pleban et al. 1995
Bacillus pumilus strain 85	Corn kernel	*Sclerotium rolfsii*	Pleban et al. 1995
Enterobacter sp.	Cotton	*Fusarium oxysporum f. sp. vasinfectum*	Chen et al. 1995
Klebsiella pneumonia	Clover root	*Rhizoctonia solani*	Struz et al.1998
Klebsiella pneumonia	Potato tuber	*Rhizoctonia solani*	Struz et al.1998
Microbacterium sp.	Cotton	*Fusarium oxysporum f. sp. vasinfectum*	Chen et al. 1995
Pantoea agglomerans	Potato tuber	*Phytophthora infestans* A1, A*2*	Struz et al. 1999
Pseudomonas fluorescens S3, *P. talaasii, P. veronii*	Rice	*Achyla klebsiana*	Adhikari et al. 2001
Pseudomonas fluorescens S3, *P. talaasii, P. veronii*	Rice	*Pythium spinosum*	Adhikari et al. 2001
Stenotrophomonas maltophilia C3	Grass foliage	*Rhizoctonia solani*	Giesler and Yuen 1998

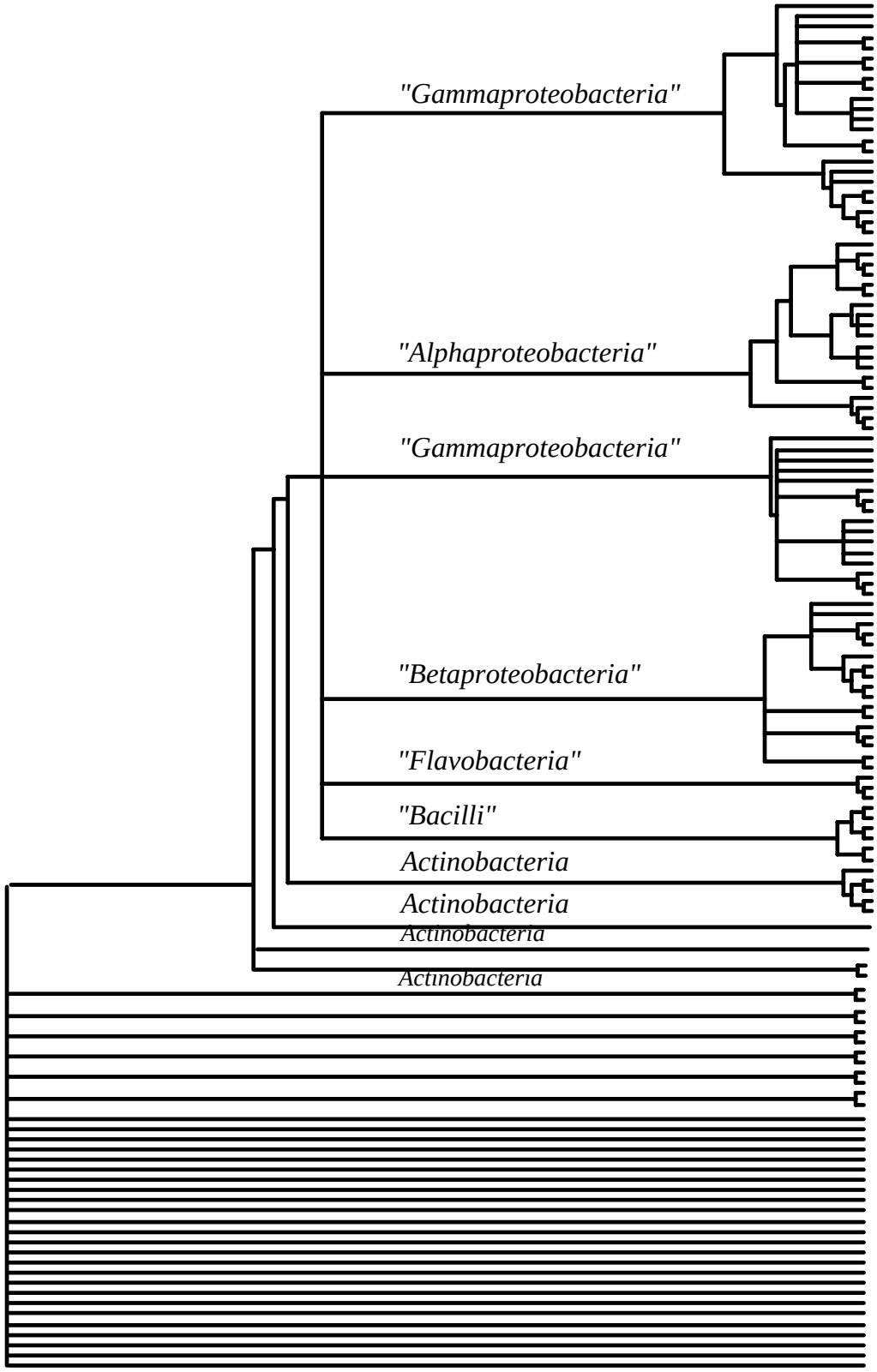
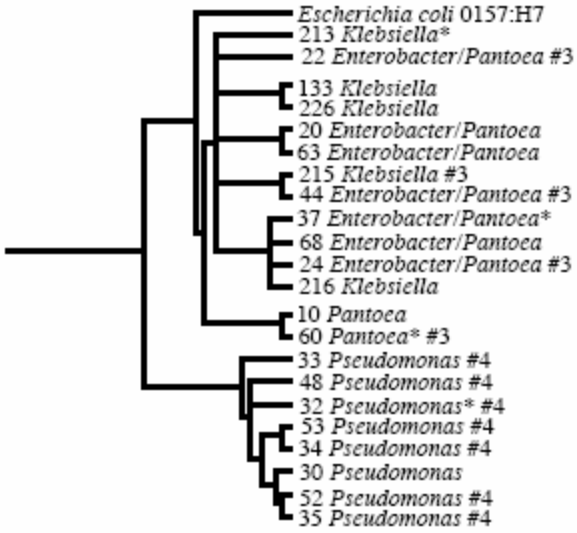


Figure 1. Neighbor-joining bootstrapped (1000 X) cladogram, bootstrap values less than or equal to 500 collapsed, of the culturable bacterial endophytes with the addition of *Bacillus megaterium* and *Escherichia coli* 0157:H7.



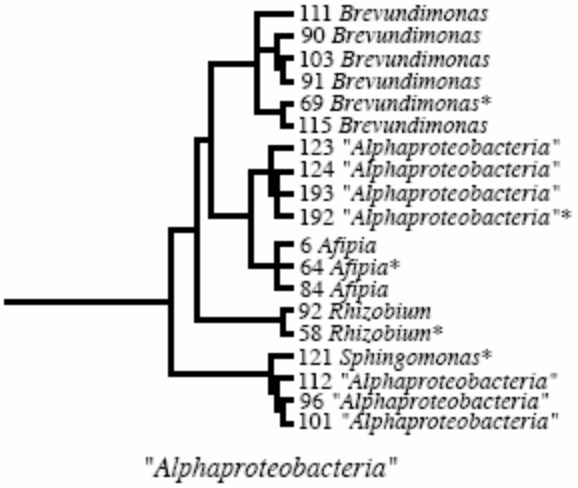


Figure 2. The *"Gammaproteobacteria"* I and *"Alphaproteobacteria"* clades from Figure 1. The asterisk indicates the clade representative sequences. The number sign denotes those endophytes with *in vitro* antagonism towards *O. herpotricha*. The following number is the antagonism rating on a scale of 0-5 with 0 indicating no antagonism and 5 the highest.

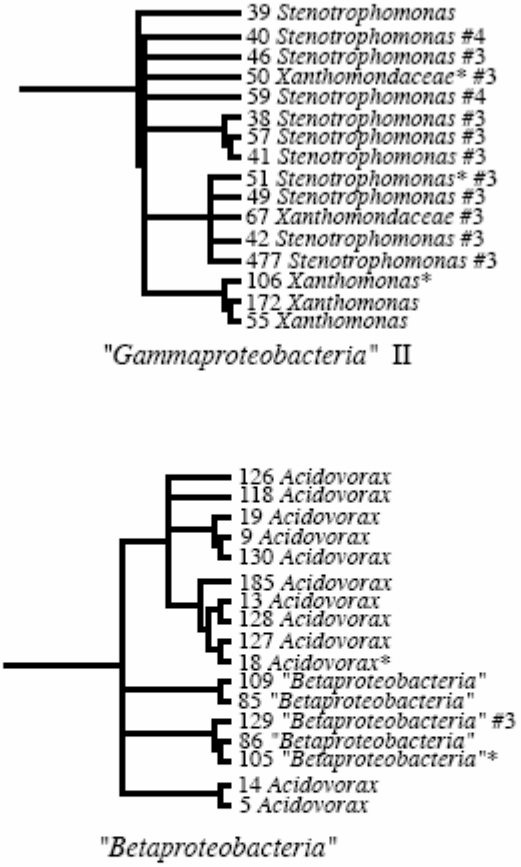


Figure 3. The *"Gammaproteobacteria"* II and *"Betaproteobacteria"* clades from Figure 1. The asterisk indicates the clade representative sequences. The number sign denotes those endophytes with *in vitro* antagonism towards *O. herpotricha*. The following number is the antagonism rating on a scale of 0-5 with 0 indicating no antagonism and 5 the highest.

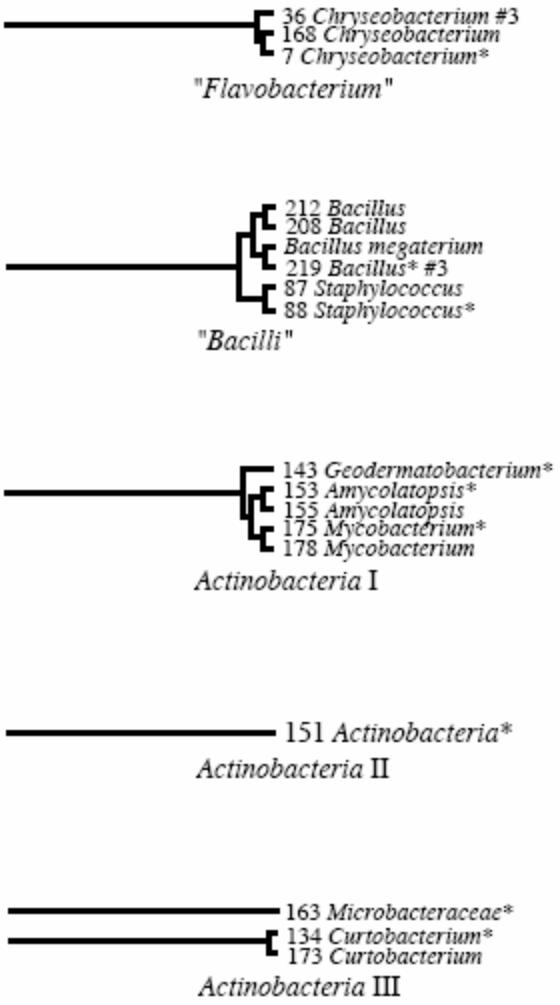
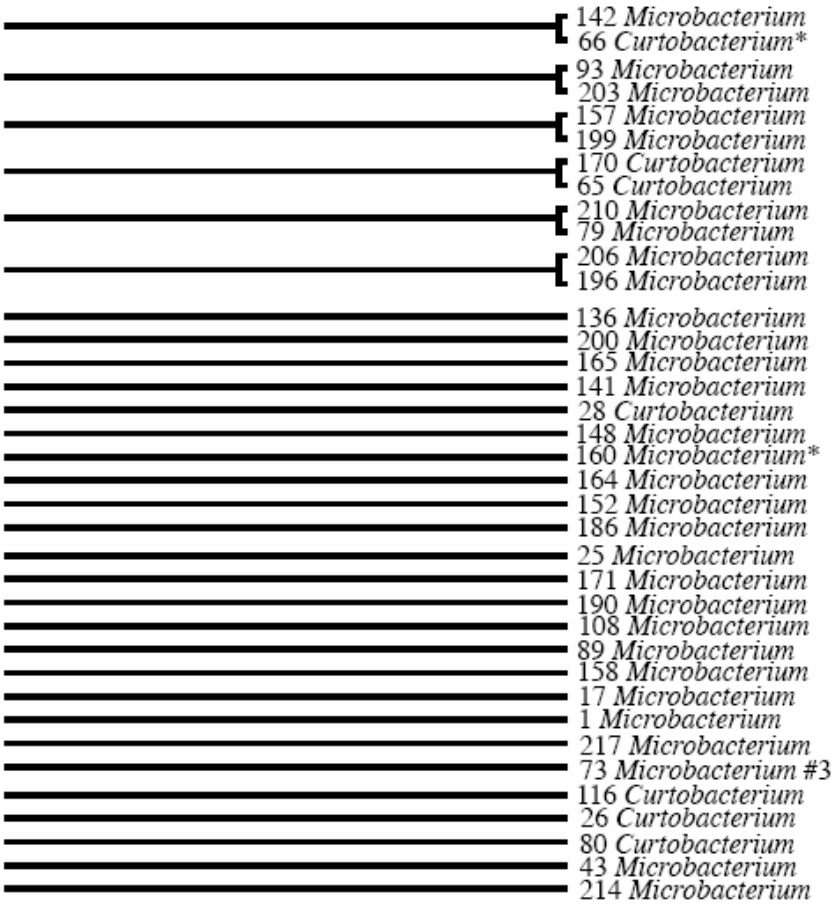


Figure 4. The *"Flavobacteria"*, *"Bacilli"*, and *Actinobacteria* I, II, and III clades from Figure 1. The asterisk indicates the clade representative sequences. The number sign denotes those endophytes with *in vitro* antagonism towards *O. herpotricha*. The following number is the antagonism rating on a scale of 0-5 with 0 indicating no antagonism and 5 the highest.



Actinobacteria IV

Figure 5. The *Actinobacteria* IV clade from Figure 1. The asterisk indicates the clade representative sequences. The number sign denotes the endophyte with *in vitro* antagonism towards *O. herpotricha*. The following number is the antagonism rating on a scale of 0-5 with 0 indicating no antagonism and 5 the highest.

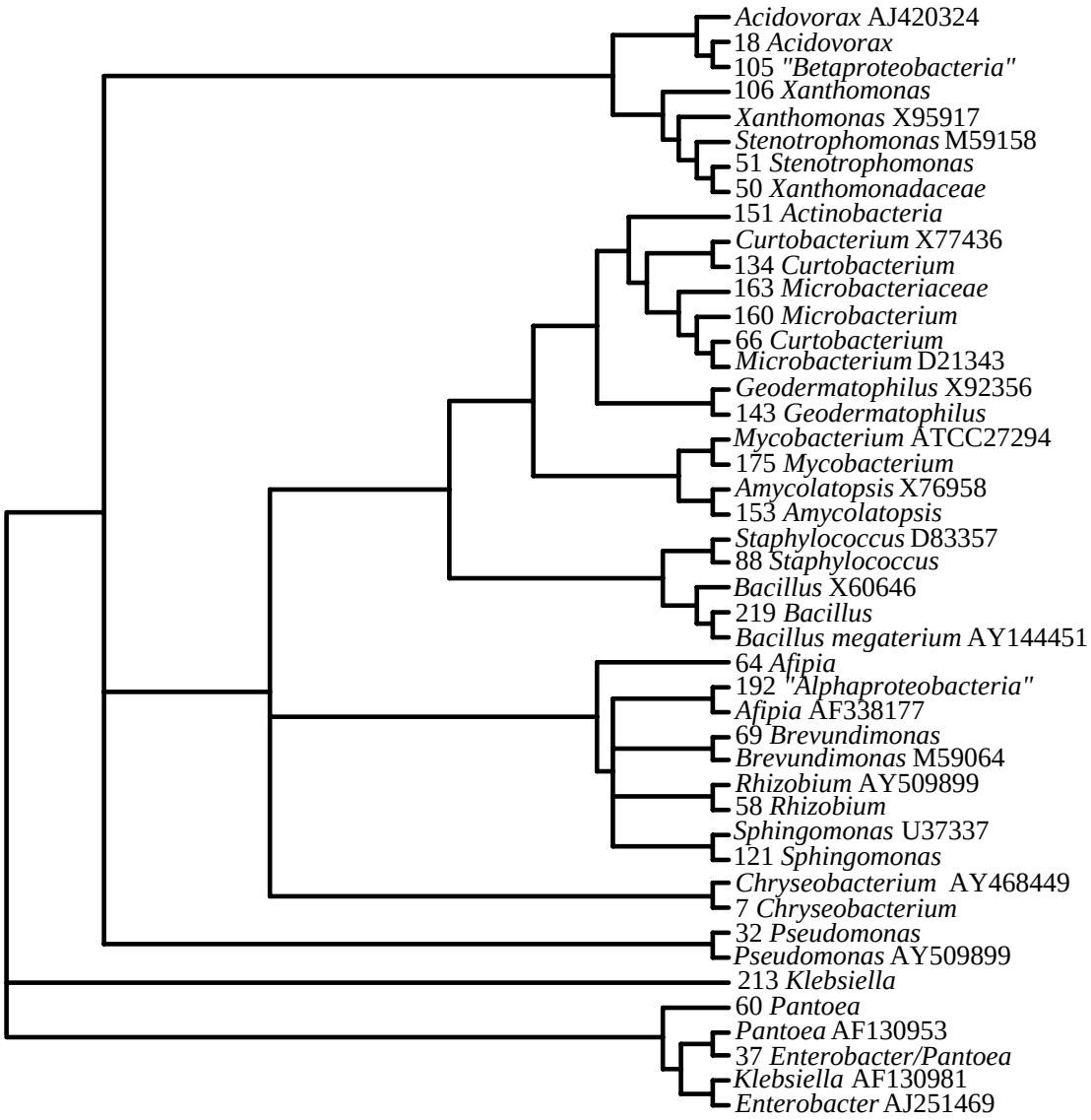


Figure 6. Neighbor-joining bootstrapped (1000 X) cladogram containing 16S rDNA sequences, 25 endophyte representatives (number, genus), *Bacillus megaterium*, and 19 type species 16S rDNA sequences. The type species name is followed by NCBI accession numbers, single and double letter prefixes or American Type Culture Collection number with the prefix ATCC.

BIBLIOGRAPHY

Adams, P. D. and J. W. Kloepper (2002). “Effect of host genotype on indigenous bacterial endophytes of cotton (*Gossypium hirsutum* L.).” Plant and Soil 240(1): 181-198.

Adhikari, T. B., C. M. Joseph, et al. (2001). “Evaluation of bacteria isolated from rice for plant growth promotion and biological control of seedling disease of rice.” Can. J. Microbiol. 47: 916-924.

Al-Musallam, A. A., S. S. Al-Zarban, et al. (2003). "*Amycolatopsis keratiniphila* sp. nov., a novel keratinolytic soil actinomycete from Kuwait." Int. J. Syst. Evol. Microbiol. 53(3): 871-874.

Altschul, S. F., T. L. Madden, et al. (1997). "Gapped BLAST and PSI_BLAST: a new generation of protein datablse search programs." Nucleic Acids Res. 25: 3389-3402.

Anonymous (1999). 1999 Turfgrass Pesticide Suggestions. Texas Agricultural Extension Service. aggieturf.tamu.edu/control.html.

Araújo, W. L., J. Marcon, et al. (2002). “Diversity of endophytic bacterial populations and their interaction with *Xylella fastidiosa* in citrus plants.” Appl. Environ. Microbiol. 68: 4906-4914.

Arvanitidou, M., A. Vayona, et al. (2003). “Occurence and anitmicrobial resistance of Gram-negative bacteria isolated in haemodialysis water and dialysate of renal units: results of a Greek mulitcentre study.” Journal of Applied Microbiology 95(1): 180-185.

Barraquio, W. L., L. Revilla, et al. (1997). “Isolation of endophytic diazotrophic bacteria from wetland rice.” Plant and Soil 194: 15-24.

Bell, C. R., G. A. Dickie, et al. (1995). "Endophytic bacteria in grapevine.P Can. J. Microbiol. 41: 46-53.

Benhamou, N., J. W. Kloepper, et al. (1996). “Induction of defense-related ultrastructural modifications in pea root tissues inoculated with endophytic bacteria.” Plant Physiol. 112: 919-929.

Bloch, K. C., R. Nadarajah, et al. (1997). “*Chryseobacterium meningosepticum*: an emerging pathogen among immunocompromised adults. Report of 6 cases and literature review.” Medicine 76(1): 30-41.

Burton, G. W. (1991). “A history of turf research at Tifton.” USGA Green Section Record 29(3): 12-14.

Chelius, M. K. and E. W. Triplett (2001). “The diversity of archaea and bacteria in association with the roots of *Zea mays* L.” Microb. Ecol. 41: 252-263.

Chung, J., S. B. Kim, et al. (1999). “*Amycolatopsis thermoflava* sp. nov., a novel soil actinomycete from Hainan Island, China.” International Journal of Systematic Bacteriology 49: 1369-1373.

Coombs, J. T., P. P. Michelsen, et al. (2003). “Evaluation of endophytic actinobacteria as antagonists of *Gaeumannomyces graminis* var. *tritici* in wheat.” Biol. Control in press.

Costa, J. L., P. Paulsrud, et al. (2001). "Genetic diversity of *Nostoc symbionts* endophytically associated with two bryophyte species." Appl. Environ. Microbiol. 67: 4393-4396.

Deacon, J. W. and L. A. Berry (1993). "Biocontrol of soil-borne plant pathogens: concepts and their application." Pestic. Sci. 37: 417-426.

Dernoeden, P. H. (2000). Maryland turfgrass disease control recommendations. Agronomy Mimeo 80. University of Maryland. iaa.umd.edu/umturf.

Dernoeden, P. H. (1999). A new fungal disease of creeping bentgrass. www.gcsaa.org/gem/1999/jun99/06creeping.html.

Dong, Z., M. J. Canny, et al. (1994). "A nitrogen-fixing endophyte of sugarcane stems: a new role for the apoplast." Plant Physiol. 105: 1139-1147.

Duble, R. L. (1996). Turfgrasses: Their Management and Use in the Southern Zone. Second Ed. Texas A and M University Press, College Station, TX. p 323.

Duffy, B. K. and G. Defago (1999). "Environmental factors modulating antibiotic and siderphore biosynthesis by *Pseudomonas fluorescens* biocontrol strains." Applied and Environmental Microbiology 65(6): 2429-2438.

Dungan, R. S., A. M. Ibekwe, et al. (2003). "Effect of propargyl bromide and 1,3-dichloropropene on microbial communities in an organically amended soil." FEMS Microbiol. Ecol. 43(1): 75-87.

Dunleavy, J. M. (1989). "*Curtobacterium plantarum* sp. nov. is ubiquitous in plant leaves and is seed transmitted in soybean and corn." Int. J. Syst. Bacteriol. 39(3): 240-249.

Elbeltagy, A., K. Nishioka, et al. (2000). "Isolation and characterization of endophytic bacteria from wild and traditionally cultivated rice varieties." Soil Sci. Plant Nutr. 46: 617-629.

Emmons, R. D. (1995). Turfgrass Science and Management. 2nd Edition. Delmar Publishers, NY. p 512.

Felsenstein, J. (1989). "PHYLIP Phylogeny Inference Package (Version 3.2)." Cladistics 5: 164-166.

Fermanian, T. W., M. C. Shurtleff, et al. (2003). Controlling Turfgrass Pests. 3rd Edition. University of Illinois at Urbana-Champaign, Urbana, IL. p 654.

Fraser, S. L. and J. H. Jorjensen (1997). "Reappraisal of the antimicrobial susceptiblities of *Chryseobacterium* and *Flavobacterium* species and methods for reliable susceptibility testing." Antimicrob. Agents Chemother. 41(12): 2738-2741.

Fravel, D. (2000). Commercial biocontrol products for use against soilborne crop diseases. www.barc.usda.gov/psi/bpdl/bpdlprod/bioprod.html.

Fry, J. and B. Huang. (2004). Applied Turfgrass Science and Physiology. John Wiley and Sons, Inc. NY. p 310.

Gagné, S., C. Richard, et al. (1987). "Xylem-residing bacteria in alfalfa roots." Can. J. Microbiol. 33: 996-1000.

Garbeva, P., L. S. van Overbeek, et al. (2001). "Analysis of endophytic bacterial communities of potato by plating and denaturing gradient gel electrophoresis (DGGE) of 16S rDNA based PCR fragments." Microb. Ecol. 41: 369-383.

Gardner, J. M., A. W. Feldman, et al. (1982). "Identify and behavior of xylem-residing bacteria in rough lemon roots of Florida citrus trees." Appl. Environ. Microbiol. 43: 1335-1342.

Garrity, G. M., B. K. Heimbuch, et al. (1996). "Isolation of zoosporogenous actinomycetes from desert soils." J. Ind. Microbiol. Biotechnol. 17(3/4): 260-267.
Gee, J. E., B. K. De, et al. (2004). "Use of 16S rRNA gene sequencing for rapid confirmatory identification of *Brucella* isolates." J. Clin. Microbiol. 42(8): 3649-3654.
Germida, J. J. and S. D. Siciliano (2001). "Taxonomic diversity of bacteria associated with the roots of modern, recent and ancient wheat cultivars." Biol. Fertil. Soils. 33(5): 410-415.
Green II, D. E., J. D. Fry, et al. (1993). "Pathogenicity of *Rhizoctonia solani* AG-2-2 and *Ophiosphaerella herpotricha* on zoysiagrass." Plant Disease 77: 1040-1044.
Hall, B. G. (2001). Phylogenetic Trees Made Ease: A How-To Manual for Molecular Biologists. Sunderland, MA, Sinauer Associates, Inc.
Hagan, A. (1997). Control of spring dead spot and bermudagrass decline. Auburn University, Alabama. www.aces.edu.
Handelsman, J. (2002). Future trends in biocontrol. In Biological Control of Crop Diseases. Ed. S. S. Gnanamanickam. New York, Marcel Dekker, Inc. p 443-448.
Holt, J. G., N. R. Kritg, et al. (1994). Bergey's Manual of Determinative Bacteriology. Ninth Ed. Williams and Wilkins. Baltimore, MD. p 787.
Hurek, T., L. L. Handley, et al. (2002). "*Azoarcus* grass endophytes contribute fixed nitrogen to the plant in an unculturable state." Molec. Plant Microbe Interact. 15: 233-242.
James, D. W. and N. I. Gutterson (1986). "Multiple antibiotics produced by *Pseudomonas fluorescens* HV37a and their differential regulation by glucose." Applied and Environmental Microbiology 52(5): 1183-1189.
Jeger, M. J. (2001). Biotic interactions and plant-pathogen associations. In Biotic Interactions in Plant-Pathogen Associations. Eds. M. J. Jeger and N. J. Spence, CAB International. p 1-14.
Jin, Z. H., J. P. Lin, et al. (2002). "Improvement of industry-applied rifamycin B-producing strain, *Amycolatopsis mediterranei*, by rational screening." J. of General and Applied Microbiology 48(6): 326-334.
Johns, R. (2004). Turfgrass Installation: Management and Maintenance. McGraw-Hill, NY. p 583.
Kageyama, B., M. Kakae, et al. (1992). "*Pantoea puctata* sp. nov., *Patoea citrea* sp. nov., and *Pantoea terrea* sp. nov. isolated from fruit and soil samples." Int. J. Syst. Bacteriol. 42(2): 203-210.
Kaplan, D. and G. A. Peters (1998). "The *Azolla-Anabaena azollae* relationship. XIV. Chemical composition of the association and soluble carbohydrates of the association, endophyte-free *Azolla*, and the freshly isolated endophyte." Symbiosis 24: 35-50.
Knutson, D. M. (1973). "The bacteria in sapwood, wetwood, and heartwood of trembling aspen (*Populus tremuloides*)." Canadian Journal of Botany 51: 498-500.
Krishna, P. S. M., G. Venkateswarlu, et al. (2003). "Biosynthesis of rifamycin SV by *Amycolatopsis mediterranei* MTCC17 in solid cultures." Biotechnology and Applied Biochemistry 37(3): 311-315.

Kudukhashvili, P. G., M. A. Gurielidze, et al. (2001). “Study of the lytic activity of actinomycetes isolated from various soils in Gerogia.” Prikl Biokhim Mikrobiol. 37(3): 289-291.

Kusel, K., H. C. Pinkard, et al. (1999). “Acetogenic and sulfate-reducing bacteria inhabiting the rhizoplane and deep cortex cells of the sea grass *Halodule wrightii*.” Applied and Environmental Microbiology 65: 5117-5123.

Lovell, C. R. (2002). Plant-microbe interactions in the marine environment. In Encyclopedia of Environmental Microbiology. Ed. G. Bitton. New York, Wiley. Vol. 5: 2539-2554.

Macur, R. E., C. R. Jackson, et al. (2004). “Bacterial populations associated with the oxidation and reduction of arsenic in an unsaturated soil.” Environ. Sci. Technol. 38(1): 104-111.

Madison, J. H. (1971). Practical Turfgrass Management. D. Van Nostrand Company, NY. p 466.

Marti, R., J. Cubero, et al. (1999). “Evidence of migration and endophytic presence of *Agrobacterium tumefaciens* in rose plants.” Eur. J. Plant Pathol. 105: 39-50.

Martin, D. and B. Hudgins. (1998). "Managing spring dead spot disease of bermudagrass, F. 7665. Oklahoma Cooperative Extension Office. Oklahoma State University.

McClung, C. R., P. van Berkum, et al. (1983a). “Enumeration and localization of N_2-fixing bacteria associated with roots of *Spartina alterniflora* Loisel.” Appl. Environ. Microbiol. 45: 1914-1920.

McClung, C. R., D. G. Patriquin, et al. (1983b). “*Campylobacter nitrofigilis* sp. nov., a nitrogen-fixing bacterium associated with roots of *Spartina alterniflora* Loisel.” Int. J. Syst. Bacteriol. 33(3): 605-612.

McInroy, J. A. and J. W. Kloepper (1995a). “Survey of indigenous bacterial endophytes from cotton and sweet corn.” Plant and Soil 173: 337-342.

McInroy, J. A. and J. W. Kloepper (1995b). “Population dynamics of endophytic bacteria in field-grown sweet corn and cotton.” Can. J. Microbiol. 41: 895-901.

Mevs, U., E. Stackebrandt, et al. (2000). “*Modestobacter multiseptatus* gen. nov., sp. nov., a budding actinomycete from soils of the Asgard Range (Transantarctic Mountains).” International Journal of Systematic and Envolutionary Microbiology 50: 337-346.

Milner, J. L., L. Silo-Suh, et al. (1996). “Production of kanosamine by *Bacillus cereus* UW85.” Applied and Environmental Microbiology 62(8): 3061-3065.

Moffat, A. (2004). Sanctuary Issue 28, Defence Estates Website. www.defence-estates.mod.uk.

Mostafa, F. I. Y. and C. S. Helling (2003). “Isolation and 16S DNA characterization of soil microorganisms from tropical soils capable of utilizing the herbicides hexazinone and tebuthiuron.” Journal of Environmental Science and Health Part B-Pesticides Food Contaminants and Agricultural Wastes 38(6): 783-797.

Mukhopadhyay, K., N. K. Garrison, et al. (1996). “Identification and characterization of bacterial endophytes of rice.” Mycopathologia 134: 151-159.

Mundt, J. O. and N. F. Hinkle (1976). “Bacteria within ovules and seeds.” Applied and Environmental Microbiology 32(5): 694-698.

Nelson, E. B. and C. M. Craft (1992). “A miniaturized and rapid bioassay for the selection of soil bacteria suppressive to Pythium blight of turfgrasses.” Phytopathology 82: 206-210.

Padma, P. N., A. B. Rao, et al. (2002). “Optimization of fermentation conditions for production of glycopeptide antibiotic vancomycin by *Amycolatopsis orientalis*.” Applied Biochemistry and Biotechnology 102: 395-405.

Page, R. D. M. (1996). "TREEVIEW: an application to display phylogenetic trees on personal computers." Computer Applications in the Biosciences. 12: 357-358.

Pair, J. C., R. A. Keen, C. M. Taliaferro, D. L. Martin, J. F. Barber and R. N. Carrow. (1994). "Registration of 'Midlawn' turf bermudagrass". Crop Science 34: 306.

Patriquin, D. G. and J. Döbereiner (1978). “Light microscopy observations of tetrazolium-reducing bacteria in the endorhizosphere of maize and other grasses in Brazil.” Can. J. Microbiol. 24: 734-742.

Philipson, M. N. and I. D. Blair (1957). “Bacteria in clover root tissue.” Can. J. Microbiol. 3: 125-129.

Pleban, S., F. Ingel, et al. (1995). “Control of *Rhizoctonia solani* and *Sclerotium rolfsii* in the greenhouse using endophytic *Bacillus* spp.” European Journal of Plant Pathology 101: 665-672.

Radianingtyas, H., G. K. Robinson, et al. (2003). “Characterization of a soil-derived bacterial consortium degrading 4-chloroaniline.” Microbiology 149(11): 3279-3287.

Reinhold-Hurek, B., T. Hurek, et al. (1986). “Close association of *Azospirillum* and diazotrophic rods with different root zones of Kallar grass.” Appl. Environ. Microbiol. 52: 520-526.

Ritter, S. K. (2003). "Green rewards." Chem. Eng. News: 30-35.

Rosado, W. and N. S. Govind (2003). “Identification of carbohydrate degrading bacteria in subtropical regions.” Revista De Biologia (Tropical 51Suppl.4): 205-210.

Sauer, K. M., S. H. Hulbert, et al. (1993). “Identification of *Ophiosphaerella herpotricha* by cloned DNA probes.” Am. Phytopath. So. 83: 97-102.

Semedo, L. T., A. A. Linhares, et al. (2001). "Isolation and characterization of actinomycetes from Brazilian tropical soils." Microbiol. Res. 155(4): 291-299.

Shishido, M., B. M. Loeb, et al. (1995). “External and internal root colonization of lodgepole pine seedlings by two growth-protomting *Bacillus* strains originated from different root microsites.” Can. J. Microbiol. 41: 707-713.

Shurtleff, M. C., T. W. Fermanian and R. Randell. (1987). Controlling Turfgrass Pests. Prentice-Hall, Inc. Englewood Cliffs, NJ. p 449.

Sivan, A. and I. Chet (1992). Microbial Control of Plant Diseases. In Environmental Microbiology. Ed. R. Mitchell. New York, Wiley. p 335-354.

Sturz, A. V., B. R. Christie, et al. (1998). “Associations of bacterial endophyte populations from red clover and potato crops with potential for beneficial allelopathy.” Can. J. Microbiol. 44: 162-167.

Sturz, A. V., B. R. Christie, et al. (1999). “Endophytic bacterial communities in the periderm of potato tubers and their potential to improve resistance to soil-borne plant pathogens.” Plant Pathol. 48: 360-369.

Sturz, A. V., B. R. Christie, et al. (1997). “Biodiversity of endophytic bacteria which colonize red clover nodules, roots, stems and foliage and their influence on host growth.” Biol. Fertil. Soils 25: 13-19.

Suman, A., A. K. Shasany, et al. (2001). “Molecular assessment of diversity among endophytic diazotrophs isolated from subtropical Indian sugarcane.” World J. Microbiol. Biotechnol. 17: 39-45.

Sundaram, S., A. Arunakumari, et al. (1988). “Characterization of *Azospirilla* isolated from seeds of turf grass.” Can. J. Microbiol. 34: 212-217.

Taliaferro, C. M. (1992). “Out of Africa - A new look at 'African' bermudagrass.” USGA Green Section Record July/August: 10-12.

Taliaferro, C. M. (1995). “Diversity and vulnerability of bermuda turfgrass species.” Crop Science 35: 327-332.

Taliaferro, C. M., D. L. Martin, J. A. Anderson, M. P. Anderson, G. E. Bell and A. C. Guenzi (2003) "Registration of 'Yukon' Bermudagrass." Crop Science 43: 1130-1131.

Taliaferro, C. M. (2005). Personal communications. Oklahoma State University, Stillwater, OK.

Tervet, I. W. and J. P. Hollis (1948). “Bacteria in the storage organs of healthy plants.” Phytopathology 38: 960-967.

Thompson, J. D., T. J. Gibson, et al. (1997). “The ClustalX-Windows interface: Flexible strategies for multiple sequence alignment aided by quality analysis tools.” Nucl. Acids res. 25: 4876-4882.

Tisserat, N. A., F. B. Iriarte, H. C. Wetzel III, J. D. Fry and D. L. Martin (2003). "Identification, distribution, and aggressiveness of spring dead spot pathogens of bermudagrass." Turfgrass and Environmental Research Online. 2(20): 1-8.

Tsuda, K., Y. Kosaka, et al. (2001). “Evaluation of the enodphyte *Enterobacter cloacae* SM10 isolated from spinach roots for biological control against Fusarium wilt of spinach.” Journal of General Plant Pathology 67(1): 78-84.

Turgeon, A. J. (2005). Turfgrass Management. 7th Edition. Pearson Prentice-Hall, Upper Saddle River, NJ.

van Berkum, P. and B. D. Eardly (2002). “The aquatic budding bacterium *Blastobacter denitrificans* is a nitrogen-fixing symbiont of *Aeschynomene indica*.” Appl. Environ. Microbiol. 68(3): 1132-1136.

Vandamme, P, J. F. Bernardet, et al. (1994). "New perspectives in the classification of the flavobacteria: description of *Chryseobacterium* gen. nov., *Bergeyella* gen. nov., and *Empedobacter* nom. rev." Int. J. Syst. Bacteriol. 44: 827-831.

Vasudevan, P., S. Kavitha, et al. (2002). Biological control of rice diseases. In Biological Control of Crop Diseases. Ed. S. S. Gnanamanickam. New York, Marcel Dekker, Inc. p 11-32.

Venkateswaran, K., N. Hattori, et al. (2003). “ATP as a biomarker of viable microorganisms in clean-room facilities.” J. Microbiol. Methods 52(3): 367-377.

Vincelli, P. and A. J. Powell. (2000). "Chemical control of turfgraass diseases 2000." Univeristy of Kentucky. www.ca.uky.edu/agc/pubs/ppa/ppa1/ppa1.htm.

Watschke, T. L., P. H. Dernoeden and D. J. Shetlar. (1995). Advances in Turfgrass Science: Managing Turfgrass Pests. Lewis Publishers. Boca Raton. p 361.

Wery, N., U. Gerike, et al. (2003). “Use of a packed-column bioreactor for isolation of diverse protease-producing bacteria from Antarctic soil.” App. Environ. Microbiol. 69(3): 1457-1464.

Wink, J. M., R. M. Kroppenstedt, et al. (2003). “Three new antibiotic producing species of the genus *Amycolatopsis*, *Amycolatopsis balhimycina* sp. nov., *A. tolypomycina* sp. nov., *A. vancoresmycina* sp. nov., and description of *Amycolatopsis keratiniphila* subsp. *keratiniphila* subsp. nov. and *A. keratiniphila* subsp. *nogabecina* subsp. nov.” Syst. Appl. Microbiol. 26(1): 38-46.

Wolters, J. (1990). Phylogeny of some gamma purple bacteria based upon 16S rRNA., National Center for Biotechnology Information. www.ncbi.nlm.nih.gov.

Zhang, H. M., A. Kallimanis, et al. (2004). “Isolation and characterization of novel bacteria degrading polycyclic aromatic hydrocarbons from polluted Greek soils.” Applied Microbiology and Biotechnology 65(1): 124-131.

Zhang, Z. and G. Y. Yuen (2000). “Effects of culture fluids and preinduction of chininase production on biocontrol of Bipolaris leaf spot by *Stenotrophomonas maltophilia* C3.” Biol. Control 18: 277-286.

Zinniel, D. K., P. Lambrecht, et al. (2002). “Isolation and characterization of endophytic colonizing bacteria from agronomic crops and prairie plants.” Appl. Environ. Microbiol. 68: 2198-2208.

DEVELOPMENT AND APPLICATION OF REAL-TIME PCR ASSAY FOR *O. HERPOTRICHA* USING TAQMAN® CHEMISTRY

ABSTRACT

Spring dead spot (SDS) is a destructive fungal disease of bermudagrass. SDS is caused by three closely related O*phiosphaerella species*, *O. korrae*, *O. herpotricha* and *O. narmari*. A real-time PCR assay with TaqMan® chemistry was developed to detect absolute quantities of *O. herpotricha* DNA in plant and soil samples from 8 SDS infected cultivars varying in resistance to SDS. Turf plugs were removed from the edge of the dead spot in November 2001 from dead spots visualized the previous spring. There were 2 of 24 plant samples from SDS-susceptible cultivars Pyramid and Princess with detectable levels of *O. herpotricha* DNA at 0.3 and 21.0 ng DNA g^{-1}, respectively. The pathogen was detected in 19 of 23 soil samples, with a range of 0.1 to 5.6 ng of *O. herpotricha* DNA g^{-1} soil. There was no obvious relationship between resistance and susceptibility of the cultivars and the levels of *O. herpotricha* DNA in plant and soil samples from the eight cultivars. The spatial distribution of *O. herpotricha* in infected SDS resistant Midlawn and susceptible Greg Norman-1 cultivars of bermudagrass was also measured. The turf plug samples were removed from the center and edge of the dead spot and at 20 and 41 cm from the edge of the dead spot in November 2001 based on spot location visualized the previous spring. The spatial distribution was patchy for both cultivars in plant and soil samples. The highest plant levels of *O. herpotricha* DNA

were 390 and 680 ng *O. herpotricha* DNA g^{-1} plant material for Greg Norman-1 and Midlawn, respectively. The highest soil levels of *O. herpotricha* DNA were 4.6 and 9.8 ng g^{-1} for Greg Norman-1 and Midlawn, respectively. There were no clear relationship between resistance of a cultivar and quantity of DNA.

INTRODUCTION

Developing a control system for plant diseases depends on understanding the factors that influence pathogen infection, plant resistance to pathogens, and pathogen distribution. Central to each of these areas is the knowledge of the presence and abundance of pathogens of interest. Until recently, researchers had limited capability to identify and quantify individual pathogens. The advent of polymerase chain reaction (PCR) techniques allowed for the sensitive detection of specific pathogens and semi-quantitative assessment of pathogen abundance. However, PCR based measurements rely on post-PCR processing steps that are time-consuming, difficult to automate, and may only be semi-quantitative at best. The development of real-time PCR methods during the last decade allows for automated, truly quantitative, analysis of pathogen DNA following each PCR amplification cycle. These advances provide for rapid, sensitive, and accurate quantification of pathogen DNA. However, this recent approach to pathogen measurement has yet to be applied in studies of fungal infections of turfgrasses. Spring dead spot (SDS), caused by three closely related species of *Ophiosphaerella* Spegazzini 1909 (*Ascomycota*), is the most destructive fungal disease of bermudagrass (Tisserat et al. 1989, Duble 1996; Watschke et al. 1995). In the United States, SDS is a

major disease in the transition climatic zone: the northern zone of bermudagrass adaptation, where autumn and winter temperatures induce bermudagrass dormancy (Wetzel III et al. 1999; Fermanian et al. 2003). SDS infects 3-6 year old highly managed turf, such as golf course fairways and greens, athletic fields, and residential lawns. SDS fungi form black plaques on root surfaces entering the root in advanced infections and eventually killing the plant. SDS is thought to be most active in the spring and fall when temperatures favor the fungal growth (Fermanian et al. 2003). Furthermore, In the fall as temperatures are lowered, infection leaves the plant weakened and more susceptible to winter kill. As the temperatures increase in the spring bermudagrass resumes its growth and the damage becomes readily apparent in the form of unsightly straw-colored, slightly depressed, round patches of turf, ranging from a few cm to about 1 m in diameter (Baird et al. 1998; Tisserat et al. 2004).

The distribution of the *Ophiosphaerella* sp. in the USA depends on geographic location. *O. herpotricha* (Fr.:Fr.) J. C. Walker infects bermudagrass in Kansas, Oklahoma, and Texas (Tisserat et al. 1989; Tisserat et al. 1994). *O. korrae* (J. C. Walker & A. M. Smith) Shoemaker & C. E. Babcock infects bermudagrass in California (Endo et al. 1985), Maryland (Crahay et al. 1988), North Carolina, Kentucky (Tisserat et al. 1994), and Australia (Tisserat et al. 1991). *O. narmari* Wetzel, Hulbert & Tisserat infects bermudagrass in Australia, New Zealand (Wetzel III et al. 1999), and California (Tisserat et al. 2003). These fungal species can be distinguished by the length of their ascospores, *O. herpotricha* the longest, *O. korrae* intermediate, and *O. narmari* the shortest. Visual identifications are difficult because the ascocarps are not easily induced in nature or in artificial media (Tisserat et al. 1994). Correct identification of the infecting SDS species

is critical because treatment may be species dependent (Tisserat et al. 2003).

Conventional PCR has been used as a diagnostic method for all three *Ophiosphaerella* spp. (Tisserat et al. 1994) and has also been used to quantify other phytopathogenic fungi (Cullen et al. 2002), but results are often unreliable (Schena et al. 2004). PCR is a cyclic reaction that is repeated many times resulting in a tremendous amplification of the target DNA. Near the end of the last cycle in the PCR, reagents become exhausted (Bohm et al. 1999) halting the reaction. For this reason, attempts to quantify the PCR product in the later cycles may underestimate the amount of target DNA. To quantify the PCR product, conventional PCR amplifications are usually followed by agarose gel electrophoresis and staining with ethidium bromide or various hybridization/blotting methods and capture techniques. These post-PCR procedures are error prone, time consuming, labor intensive, and impractical to automate, and they generate environmental wastes (Chen et al. 1997; Oberst et al. 1998; Bohm et al. 1999; Zhang and Yuen 1999).

A real-time quantitative PCR with TaqMan® probes was developed about 10 years ago, providing rapid, sensitive, and accurate quantification of target DNA. Early reports of real-time quantitative PCR with TaqMan® chemistry include the detection of the food-borne bacterial human pathogens *Listeria monocytogenes* (Bassler et al. 1995), *Salmonella* (Chen et al. 1997), and *Escherichia coli* Migula 1895 O157:H7 (Oberst et al. 1998). Some of the first applications in plant pathology include real-time PCR assays of pathogens in plant tissues including the *potato leafroll virus* (Schoen et al. 1996), the fungi *Diaporthe phaseolorum* (Cook & Ellis) Sacc. 1882, and *Phomophsis longicolla*

(Zhang and Yuen 1999). These early successes led to more recent applications of TaqMan® methods including measurements of phytopathological fungi in both plant and soil, quantifying *Helminthosporium solani* Durien & Mont. 1849 (Cullen et al. 2001), *Rhizoctonia solani* J. G. Kuhn 1858 AG-3 (Lees et al. 2002), and *Colletotrichum coccodes* (Wallr.) S. Huges 1958 (Cullen et al. 2002). To date, there has been no assay to quantify *Ophiosphaerella sp.* DNA in the natural environment. This study is the first to develop real-time PCR for quantifying the causal agent of spring dead spot, *O. herpotricha*.

The technology of real-time PCR with TaqMan® probes is based on the use of PCR forward and reverse primers for DNA amplification and a fluorescent probe complementary to a specific internal sequence of the target DNA for specific detection. The 5' end of the probe is labeled with a fluorescent reporter dye and the 3'end is labeled with a quencher. When the probe is in the free state in solution or hybridized to the amplified DNA, little if any fluorescence is generated due to the close proximity of the quencher dye to the fluorescent moiety. During PCR both forward and reverse primers anneal to their priming sites and the TaqMan® probe anneals internally within the target DNA. During the PCR extension phase, while DNA is being copied and as the polymerase contacts the internally annealed TaqMan® probe, the 5'-exonuclease activity of the *Taq* polymerase releases the 5' fluorescent dye from hybridized probes. The released dye is able to fluoresce upon excitation because it is no longer in close proximity to the quencher dye. Upon excitation, the real time PCR Thermal Cycler detects and records the accumulation of fluorescence in the sample after every cycle (Mumford et al.

2000; Winton et al. 2002; Mayer et al. 2003). In addition, the TaqMan® probe exhibits a high degree of specificity for hybridizing to the target DNA. The probe is so specific that it will not detect DNA sequences differing from the target by a single nucleotide (Schena et al. 2004). The real-time PCR assay is extremely sensitive and can detect a single copy of target DNA in specific systems (Zhang and Yuen 1999). As many as 384 samples can be run at a single time, in as little as 3 hours, making it one of the highest throughput systems available for detecting and quantifying nucleic acids. Furthermore, selective quantification of target DNA is available at the end of the real-time PCR assay, eliminating the need for time consuming post-PCR methods (Zhang and Yuen 1999; Cullen et al. 2002; Atkins et al. 2003).

There are two methods to quantify the amplification of DNA in sample extracts, relative and absolute quantification. Relative quantification analyzes changes in gene expression in a given sample relative to a reference sample. Relative quantification is useful if one is most interested in comparing DNA concentration among experimental treatments. Absolute quantification measures amplified DNA by interpolating the amplicon quantity from a standard curve generated from DNA standards of known concentration (Applied Biosystems 2005). Absolute quantification is required if one is interested not only in the relative amounts among experimental treatments, but also the concentration of DNA. Absolute quantification is essential if one is interested in determining DNA concentrations over an extended time period where it would be difficult to run all samples at a given time.

In this report, we describe the development of a real-time PCR assay for the absolute quantification of *O. herpotricha* DNA. The objectives of our study were aimed

to: (1) optimize a real-time quantitative PCR assay with TaqMan® probe/primer set to quantify *O. herpotricha* in bermudagrass plant tissue and soil samples, (2) use this assay to document the spatial distribution of *O. herpotricha* infection, and (3) document the relationship between resistant and susceptible cultivars of bermudagrass and SDS.

MATERIALS AND METHODS

All bermudagrass plots used in this study were located at the Oklahoma State University Turfgrass Research Center, Stillwater, Oklahoma under the direction of Dr. Dennis Martin, Department of Horticulture and Landscape Architecture, Oklahoma State University. Samples of turf were removed November 21, 2001 from 2 to 6 PM using a plug cutter, extracting a core 2.5 cm diameter X 6 cm long. Each individual plug location was chosen from a site characterized for infection with *O. herpotricha* during the previous spring. The plug cutter was washed in fresh water and scrubbed with a bottle brush to remove all plant and soil material before the next sampling. The harvested plugs were placed separately into individually labeled zip-lock plastic bags stored on ice, transported back to the lab, and stored at 4 °C for further processing.

Sample Harvesting for Measuring Spatial Distribution of *O. herpotricha*

Eighteen to 22 bermudagrass plugs were harvested from each of three plots of the resistant cultivar Midlawn and the highly susceptible cultivar Greg Norman-1 (GN-1) plots (Figs. 7-12). Plugs were cut from the center, periphery, and 20 and 41 cm from the periphery of the dead spot. Unequal sampling from each of these locations occurred as an oversight. Plugs from GN-1 Plots B and C and Midlawn Plots A and C were arranged in a radial pattern as illustrated (Figs. 8-10, 12). However, sampling had to be altered

because some of the dead spots were too close together. This occurred in Midlawn Plot B (Fig. 11) and GN-1 Plot A, where dead spots overlapped significantly (Fig. 7).

Sample Harvesting for 8 Cultivars of Bermudagrass

Bermudagrass cultivars OKC 19-9, 'Patriot' (OKC 18-4) [*Cynodon dactylon* L. (Pers.) X C. *transvaalensis* Burt-Davies], Tifway, Numex Sahara, Mirage, Sydney (SW 1-7), Pyramid, and Princess were selected to represent a wide range in resistance and susceptibility to *O. herpotricha*. For each cultivar a total of 12 plugs, four plugs from the periphery of the dead spot in each of three plots, were collected in November whose location was determined by the location of the dead spot in the previous spring:.

Total Plant DNA Isolation

The plant component of each plug was separated from the soil component manually, and the soil component was reserved for total soil DNA extraction. The plant material was placed in a plastic weigh-boat and scrubbed gently in several changes of Nanopure water (Barmstead, Dubuke, IA) with a toothbrush until the water was clean, approximately 4 changes of water. A clean weigh-boat was used for each plug. The crown tissue, rhizomes, and stolons were excised from the roots and stems using an 70 % ethanol washed razor blade. The crown tissue, rhizomes, and stolons were combined and placed into a 1.7 mL or 15 mL centrifuge tube depending on the mass of tissue. The tubes were sealed with two layers of Parafilm® and capped, frozen at –20 ° C for two hours, then lyophylized overnight (Labconco, Kansas City, MO). The tubes were stored at –20 ° C until processed further. The plant material was ground under liquid nitrogen to a fine powder using a mortar and pestle, and the DNA was isolated using the DNeasy®

Plant Mini Kit (Qiagen Inc., Valencia, CA) following manufacturer's instructions. The isolated DNA was stored at –20 °C.

Total Soil DNA Isolation

In the laboratory, roots were carefully removed from the soil plug and the soil saved in 1.7 mL or 15 mL centrifuge tubes. The tubes were sealed with two layers of Parafilm® and frozen at –20 °C for 2 hours, then lyophylized overnight and stored at –80 °C. Total soil DNA was isolated using the UltraClean™ Soil DNA Isolation Kit (MoBio Inc., Sunnyvale, CA) following manufacturer's instructions for maximum yields. The isolated DNA was stored at –20 °C.

O. herpotricha Genomic DNA Isolation

Using sterile technique, *O. herpotricha* hyphae growing on nutrient agar (Sigma, St. Louis, MO) were scraped into a 500 mL flask containing with 250 mL of nutrient broth (Becton Dickinson, Cockeysville, MD) and shaken at 150 rpm for seven days at room temperature. Under these conditions the fungus hyphae formed a spherical matt which were recovered by filtration through a Buchner funnel lined with a paper filter. The hyphae were transferred to 15 mL centrifuge tubes, sealed with two layers of Parafilm®, frozen at –20 °C for 2 hours, and then lyophylized overnight. The lyophylized hyphae were ground under liquid nitrogen and stored in 1.7 mL microcentrifuge tubes at –80 °C. The DNeasy® Plant Mini Kit was used to isolate genomic DNA from *O. herpotricha* following manufacturer's instructions using 23 mg of ground lyophilized *O. herpotricha* hyphae per extraction.

O. herpotricha Primers and TaqMan® Probe

The primers and TaqMan® probe were designed to amplify and detect *O. herpotricha* DNA of the internal transcribed spacer (ITS) region (Tisserat et al. 1994), and were designed from a series of primers generated by the Primer Express Version 1.0 software (Applied Biosystems, Foster City, CA). The software generates a series of primer/probe combinations and ranks them according to a penalty score following certain guidelines for optimizing the TaqMan® probe sequence. The DNA sequence should have a T_m of 68 – 70 °C to ensure the probe hybridization to the complementary target prior to polymerase extension. The 5' end of the probe should be as close to the 3' end of the primer without overlapping to ensure immediate displacement and cleavage of the fluorescent dye by the polymerase. Guanine should not be at the 5' end of the probe sequence because guanine quenches the fluorescence of the fluorescent dye. Also runs of 4 or more guanines should be avoided because of possible excessive fluorescence quenching (Applied Biosystems 2002; Bustin and Nolan 2004).

Primers were synthesized by the Nucleic Acids Core at the Pennsylvania State University, University Park, PA. The forward primer was 5' TGA ACC TGC GGA AGG ATC A3', 19 bases long, with a T_m of 59 ° C, and % GC of 53. The reverse primer was 5' GTA ATA GAC ATA ACC CGT CTG CGT AG 3', 26 bases long with a T_m of 58 ° C and % GC of 46. The TaqMan® probe (Biosearch Technologies, Inc., Novato, CA) sequence was 5' 6-FAM d(ACA CGA TAG TAC AGG CCC CAA GTG TAG AAC AA)BHQ-1 3', 32 bases long with a T_m of 68 ° C and % GC of 47. The reporter dye, 6-FAM (6-carboxyfluorescein), has a maximum excitation wavelength of 494 nm (±5 nm). The quencher dye is a black hole quencher, BHQ-1 (4-methyl-2-nitrobenzylazo-

2'methyl-5'-nitrobenzylazo-4"-N,N-di(2-hydroxyethyl) azobenzene), with a maximum quenching wavelength of 534 nm (±5 nm). The PCR amplicon was 80 bases long with a T_m of 78 °C, and % GC of 46.

Real-Time PCR Master Mix and Real-Time PCR Cycle

The real-time PCR master mix for each 100 µL reaction was composed of 25.0 µL of Universal Master Mix (ABI PN# 4304437, or Eurogentec RT-QP2X-03WOU), 2.0 µL of primer 1450 for a final concentration of 400 nM, 2.0 µL of primer 1451 for a final concentration of 400 nM, 10.0 µL of TaqMan® probe for a final concentration of 200 nM, 6.0 µL of water, and 5.0 µL of plant or soil extract.

The real-time PCR light cycler (ABI Prism 7700 sequence detector, Applied Biosystems, Foster City, CA) at the Nucleic Acids Core of the Pennsylvania State University was programmed as follows: Stage One at two min at 50 ° C; Stage Two at ten min at 95 ° C to hold; then Stage Three at 45 cycles at 15 sec at 95 ° C, one min at 60 ° C; followed by a final hold at two min at 25 ° C. Stage One digests the uracil-N-glycosylase. Stage Two denatures uracil-N-glycosylase and activates the Ampli-taq Gold DNA polymerase. Stage Three amplifies the amplicon (Lees et al. 2002). Sample fluorescence was measured for each sample after stage three of each cycle.

Standard Curve for Real-Time PCR

A serial dilution was made from a stock solution of 31 ng of *O. herpotricha* genomic DNA μL^{-1}. The final concentrations of the standards were obtained by diluting the stock concentration ten fold in a series of five steps (from 3.1 ng μL^{-1}, to 0.00031 ng μL^{-1}). A standard curve of *O. herpotricha* DNA was generated by amplifying 5.0 µL of each dilution in 95 µL of Master Mix. The dilution series was run three times and the

values were averaged. All five standards were included in one 96-well plate per day of analyses.

Analyses of Real-Time PCR Data

The ABI Prism 7700 software (Applied Biosystems, Foster City, CA) recorded the fluorescence of each reaction for every PCR cycle, created a real-time amplification plot, calculated threshold cycle (C_t) values, and generated a standard curve graph. The C_t value is a preset value that is near the front end of the linear range of the real-time PCR response curve. Absolute quantitation of *O. herpotricha* DNA was calculated based on the regression equation derived from the standard curve of C_t values vs. absolute amount of *O. herpotricha* DNA.

Optimization of *O. herpotricha* Amplification in Plant and Soil Samples

The *O. herpotricha* primers, TaqMan® probe, and light cycler parameters were optimized using DNA extracts from 4 GN-1 plugs removed from the periphery of the dead spot because these samples had the highest probability of being infected with *O. herpotricha*. A series of 10 fold dilutions was prepared for each of the plant and soil DNA extracts. The addition of polyvinylpyrrolidone (PVP-40), 8 % final volume, was added to half of the samples and was found to be necessary for generating good amplification signals.

Specificity of the *O. herpotricha* Primers and TaqMan® Probe Set

Genomic DNA isolated from *Rhizoctonia solani* and *Pythium arrhenomanes* were tested against the *O. herpotricha* primers and TaqMan® probe set. A negative control, Buffer AP1 from the DNeasy® Plant Mini Kit (Qiagen Inc., Valencia, CA), and a positive

control, *O. herpotricha* genomic DNA, were included in the same 96-well plate as the *R. solani* and *P. arrhenomanes* samples.

Statistical Analyses

Statistical analyses of *O. herpotricha* DNA concentrations in extracts of plant and soil samples were performed in collaboration with Professor Mark Payton of the Department of Statistics, Oklahoma State University, Stillwater, OK. DNA concentrations were transformed using a logarithm transform, and ANOVA was performed using PROC MIXED option of SAS software (SAS 2001). A multiple comparison was performed by looking under differences in least square means.

RESULTS

O. herpotricha Primers and TaqMan® Probe Set

The sequence similarity of the forward and reverse primers and the TaqMan® probe for detection of *O. herpotricha* were evaluated individually by basic local alignment search tool (BLAST) alignment (Altschul et al. 1997) against the National Center for Biotechnology Information (NCBI) sequence database. The nucleotide sequence of the forward primer matched accessions from *O. herpotricha* (U04861) and *O. korrae* (U04862) (Tisserat et al. 1994) perfectly (Table 22) as well as those of 20 other genera of fungi, including: *Coprinus* Pers. 1797 (AY461840 (Keirle et al. 2003)), *Corprinopsis* (AY461833 (Keirle et al. 2003)), and *Inonotus* P. Karst. 1879 (AY436626 (Yun et al. 2003)). The reverse primer showed 100% similarity in all 26 base pair (bp) positions to four *O. herpotricha* strains, including: U04861, AF101797, AF101796, and

AF101795 (Wetzel III et al. 1998). The NCBI BLAST match for the 31 bp TaqMan® probe DNA sequence showed a 100% match with only one strain of *O. herpotricha* (U04861) and a single base pair deviation with two other strains of *O. herpotricha* (AF101795 and AF101798 (Wetzel III et al. 1998)). A single match with 2 base pair deviation was observed with *O. namari* (AF101803 (Wetzel III et al. 1998)).

Experimental Verification of Selectivity

The specificity of the real-time PCR assay was evaluated by analyzing genomic DNA extracted from *Pythium arrhenomenes* (*Oomycota*) and *Rhizoctonia solani* (*Basidiomycota*) two fungal species widely divergent from *Ophiosphaerella* sp. (*Ascomycota*). Duplicate analyses of reaction mixtures containing either 62 ng of *R. solani* DNA or 145 ng of *P. arrhenomenes* DNA failed to give threshold fluorescence after 45 amplification cycles.

Sensitivity and Dynamic Range of the Real-Time PCR Assay

Sensitive quantification of *O. herpotricha* DNA was achieved using the forward and reverse primers in conjunction with the TaqMan® probe described above. For each day plant and soil samples were assayed, DNA standard solutions ranging in concentration from 3.1 ng to 310 fg of *O. herpotricha* DNA μL^{-1} were analyzed in duplicate to construct a standard curve (Fig. 13). The assay performance varied slightly, (relative standard deviation (RSD) = 7 %), day to day, and easily detected the lowest concentration (310 fg) *O. herpotricha* DNA standard spanning range of four orders of magnitude. The least-squares best fit of log[DNA] vs. cycle number for threshold detection gave correlation coefficients ranging from R^2=0.921 to 0.997.

Optimization for Matrix Effects

Initial measurements performed on extracts of GN-1 plant samples from two plugs collected from the periphery of the dead spot yielded positive detection of *O. herpotricha* in both plant samples (Table 23). Further experiments were conducted to optimize the PCR reaction by diluting the plant and soil samples or by adding the phenolic scavenger PVP to the extract. In addition, we spiked the plant and soil samples with known amounts of DNA to observe the effect of additional DNA on the amplification process. As expected, diluting the plant samples 10 fold increased the Ct values by 6.7 cycles in non-PVP treated and 4.5 cycles in the PVP treated tissues. Addition of PVP to the plant samples yielded an increase of 4.4 cycles in full strength samples and 2.2 cycles in the 10 fold diluted samples. Spiking the real-time PCR amplification mixture with a relatively large amount of *O. herpotricha* DNA (1 ng) resulted in an expected and dramatic reduction in numbers of cycles from an average of 38 cycles to 21.5 cycles. Neither PVP nor dilution was employed in subsequent plant samples real time PCR measurements because the optimization experiment without PVP and dilution amplified *O. herpotricha* DNA.

When the same initial experiments were performed on soil samples no pathogen DNA was detected. To test our hypothesis that soil extracts might contain inhibitory substances, the soil extracts were spiked with 1 ng of *O. herpotricha* DNA and PVP, 8 % final volume, and analyzed again (Table 23). In contrast to the results from plants, no pathogen DNA was detected in spiked soil extracts at full strength (1X). Dilution of soil extracts and the addition of PVP reduced the inhibition in real-time PCR samples from unknown inhibitory substances. Diluting the spiked soil DNA extracts 10- and 100-fold

resulted in dramatic reduction in average cycle numbers when compared to undiluted extracts from 44.5 to 23.2. These results for spiked DNA samples were similar to those obtained from equivalent concentrations of *O. herpotricha* DNA in buffer (data not shown). Soil extracts diluted 10 and 100 fold showed no detectable levels of pathogen DNA. In subsequent real-time PCR assays, soil samples were conservatively diluted 100-fold and PVP, 8 % final volume, was added.

Sample to Sample Variation

The reproducibility of the real-time assay was high for both plant and soil samples (n=2). Replicate analyses were compared for a total of 149 plant and 147 soil assays yielding an average standard deviation of 0.29 and 0.54 $C_{t,}$ respectively.

Use of Assay – 8 Cultivar Study

To test the real-time PCR assay, field samples were assayed for *O. herpotricha* DNA in three triplicate pooled plant and soil samples from eight bermudagrass cultivars (Table 24). The samples were collected around the periphery of the infection zone. The pathogen was detectable in only one plant extract from each of two most susceptible cultivars, Princess and Pyramid, with 21 and 0.3 ng of *O. herpotricha* DNA $gram^{-1}$ plant material, respectively. The most susceptible cultivars were the only ones to show any detectable levels of pathogen DNA with this technique. The levels of detection were well above the background level of the assay. The pathogen was detected in 19 of 23 soil extracts ranging as high as 5.6 ng of *O. herpotricha* DNA $gram^{-1}$ soil in replicate 2 of Tifway and as low as 0.1 ng in rep 3 of Princess and rep 1 of Numex Sahara. In contrast to the plant DNA, the results showed little relationship to cultivar susceptibility. The

highest soil values were found in cultivar Tifway and the lowest with Patriot soil extracts. Every cultivar gave at least one positive soil assay result.

Spatial Distribution of *O. herpotricha* in Spots with Susceptible Greg Norman-1

The real-time PCR assay was used to document the spatial distribution of *O. herpotricha* in plant and soil samples for susceptible GN-1 cultivars. Samples were obtained from infection zones during the spring when spots were visible. Sampling was done in the center of the spot where the turfgrass had died, the periphery where the grass was thinned, and at two locations successively more distant from the periphery. Real-time PCR assays were performed on both soil and plant materials. Higher average readings of *O. herpotricha* were found in the plant material than in the soil. Although there were no statistically significant differences among the various geographical locations in the plant material, there was a trend in that direction ($p=0.11$). The lack of statistically defined differences reflects wide fluctuations in readings from sample to sample. Standard deviations of the data ranged from 2.8-1.2 times the absolute value of the average value itself. Despite the lack of statistically discernable differences, average DNA concentrations in the plant material tended to be higher in the center and the periphery than away from the periphery. On average, decreasing levels occurred in plant material from 20 and 41 cm from the periphery. The highest levels were found in the center of the dead spot in Plot A at 390 ng g^{-1} sample. Plot A had much greater average levels of *O. herpotricha* DNA than either Plot B or C. Only three samples from Plot B showed any detectable levels of *O. herpotricha* DNA.

Readings for the soil extracts from the GN-1 were all very low with numerous non-detects. There were no significant differences ($p= 0.482$) among the different

locations due to the wide degree of variability and low readings of the fungus in the soil. In contrast to the plant extracts, the soil extracts from GN-1 Plot B were all below the limits of detection (Table 25). The soil extracts from GN-1 Plots A and C contained generally the same levels of *O. herpotricha* DNA in the four sampling sites ranging from non-detects to 4.6 ng *O. herpotricha* DNA gram^{-1} soil.

Spatial Distribution of *O. herpotricha* in Spots with Midlawn

The real-time PCR assay was used to document the spatial distribution of *O. herpotricha* in plant and soil samples for resistant Midlawn cultivars (Table 26). In contrast to Greg Norman-1, Midlawn plant samples showed much lower real-time PCR readings. However, the differences between cultivars were not significantly different. Midlawn plant extracts from Plot A had readings of *O. herpotricha* DNA slightly above the limits of detection (Table 26) in all but 6 samples. Only 2 positives were found in Plot B and one in Plot C. The one positive in Plot C was the highest level found in all plant and soil samples collected in this study, at 680 ng DNA g-1. There were no significant differences among the means with respect to location in plant samples in the Midlawn plots.

The readings of *O. herpotricha* DNA in the Midlawn soil extracts ranged from non-detects to 8.9 ng of *O. herpotricha* DNA gram^{-1}. The level of *O. herpotricha* DNA was higher in the periphery in the soil extracts from the Midlawn plots than from the other locations. This coincides with the Greg Norman-1 plant tissues but not in soil samples, nor in the Midlawn plant samples.

DISCUSSION

Goals of This Study

The goals of this study were to (i) develop a real-time quantitative PCR assay using TaqMan® chemistry to quantify the soil phytopathogen *O. herpotricha* in plant and soil samples, (ii) use this assay to compare levels of *O. herpotricha* DNA in crown tissue of resistant and susceptible cultivars of bermudagrass and in associated soil, and (iii) document the spatial distribution of SDS in crown tissue and soil for two cultivars of bermudagrass, resistant Midlawn and susceptible Greg Norman-1. The performance of the assay was evaluated based on its specificity for detection of *O. herpotricha* DNA against two unrelated fungal genera, the ability of the assay to quantify low levels of DNA from this pathogen in plant and soil matrices, and the dynamic range of the assay response over a wide range of DNA concentrations.

The real-time quantitative PCR assay using TaqMan® chemistry and absolute measurements was developed to detect *O. herpotricha* DNA in plant and soil samples with a limit of detection of 31 fg *O. herpotricha* DNA g^{-1} sample. Four strains of *O. herpotricha* and one strain of *O. narmari* can be theoretically detected by the assay. *R. solani* and *P. arrhenomanes* genomic DNA was not detected by the real-time PCR assay. This assay exhibits the sensitivity and selectivity necessary for its application in studies of *O. herpotricha* infections.

Assay Selectivity

The *O. herpotricha* primers and TaqMan® probe were selected from the ITS rDNA sequence of *O. herpotricha* strain (Tisserat et al. 1994). The ITS region was used because it is a species specific hypervariable region and there are over 100 copies per haploid genome in many fungi (Tisserat et al. 1994; Bohm et al. 1999; Atkins et al. 2003), allowing for potential detection of very low levels of *O. herpotricha* compared to assays detecting single copy sequences per haploid genome, e. g. β-tubulin gene (Winton et al. 2002). Based on the forward and reverse primers alone, the real-time PCR assay will be selective for four strains of *O. herpotricha* (U04861, AF101795, AF101796, and AF101797). There is a possibility the assay will detect one strain of *O. narmari* (AF101798) because the reverse primer may initiate amplification and the TaqMan® probe will base pair with the amplicon (Table 22). This possibility needs to be experimentally examined. Based on the theoretical specificity of the TaqMan® probe, other related fungi including *O. korrae* and *Leptospharella korrae* (syn = *O. korrae*) differ from the TaqMan® probe sequence in two or three bases and all other database entries gave yet poorer matches. The selectivity of the TaqMan® probe sequence will not allow annealing to DNA sequences with 2 or more mismatched bases (Schena et al. 2004). We anticipate our TaqMan® probe will not detect non-*O. herpotricha* organisms, except *O. narmari* (AF101798). The combined theoretical specificity of the forward and reverse primers with the TaqMan® probe should make this assay specific for only one fungal species, *O. herpotricha*.

The specificity of the *O. herpotricha* assay was tested against *Pythium arrhenomenes* and *Rhizoctonia solani* genomic DNA, two species that are widely divergent from the *Ophiosphaerella* sp. During the real-time PCR analyses, fluorescence did not rise above the threshold levels, indicating the *O. herpotricha* assay did not detect *P. arrehenomenes* and *R. solani* DNA. Access to pure cultures of other fungal species was limited, therefore only 2 phytopathogenic fungi were evaluated using this assay. In the future, closely related fungal strains should be tested with this assay to determine the specificity. However, recent reports of other real-time PCR assays of microbial DNA using TaqMan ® chemistry have demonstrated selective detection of target sequences (Olivira et al. 2002; Mayer et al. 2003; Cullen et al. 2001) when tested against numerous fungal or bacterial species. The selectivity of the TaqMan® assay developed in the current study is expected to be high based on the 2001 report from Merck Research Laboratories that 1000-fold discrimination was obtained for sequences differing by a single nucleotide (Bleicher et al. 2001).

Limits of Detection and Dynamic Range for *O. herpotricha* Genomic DNA

The dynamic range, the span of the standard curve between the highest and lowest concentration of *O. herpotricha* DNA, and limits of detection were determined by measuring the number of cycles needed to achieve threshold fluorescence for serial dilutions of *O. herpotricha* genomic DNA. The linear range of the *O. herpotricha* DNA standard curve spans at least 4 orders of magnitude, from 31 fg to 3.1 ng of *O. herpotricha* DNA μL^{-1}. The dynamic range is comparable to that in assays developed for *Glomus mosseae* (T. H. Nicolson & Gerd.) Gerd. & Trappe 1974, *Phytophthora citricola* Sawada 1927, *P. infestans* (Bohm et al. 1999), *Diaportha phaseolorum*, *Phomopsis*

longicolla Hobbs 1985 (Zhang and Yuen 1999), and *Phaeocryptopus gaeumannii* (T. Rohde) Petr. (Winton et al. 2002).

The limits of detection were 1.4, 3.9, and 26.3 fg of *O. herpotricha* DNA μL^{-1} for three separate but identical real-time PCR assays, as determined from three standard curves generated on three different days when optimization and experimental samples were assayed. These assays were performed in the same laboratory with the same light cycler. Samples that gave a mean of 42 C_t almost always had one replicate that did not reach threshold fluorescence, and were considered below the limits of detection.

Interference by Sample Matrix, Plant and Soil Samples

The challenges in developing this particular assay lie in optimizing conditions for analysis and determining limits of detection in plant and soil samples. The plant and soil DNA extracts were tested to determine if the real-time PCR assay would amplify *O. herpotricha* DNA. The full strength plant extract matrix did not inhibit DNA amplification compared to plant extracts spiked with 1 ng of *O. herpotricha* DNA μL^{-1} and non-spiked extracts (Table 23) suggesting that inhibitory compounds may not be present in the plant extracts. PVP occasionally had a small inhibitory effect on DNA amplification when comparing the change in C_t for plant and soil samples with and without PVP to real-time PCR blanks. However, the full strength soil extract matrix inhibited DNA amplification for both *O. herpotricha* spiked and non-spiked extracts. Diluting the soil extract dramatically lowered the number of cycles in an assay indicating there may be some inhibitory substances in the soil matrix. Subsequent soil assays at 1:10 and 1:100 dilutions, with and without PVP 8% final volume, were equally successful in DNA amplification. These results led us to chose, conservatively, a 1:100

dilution with PVP, 8% final volume, to ensure successful amplification of the remaining soil samples, even though the 1:10 dilution without PVP was sufficient for the test soil sample. The optimization process was easy, quick, and simple and requires minimal laboratory skill.

For analysis of plant and soil samples, the *O. herpotricha* real-time PCR assay limit of detection was always less than 30 fg μL^{-1} as determined by extrapolating the standard curve to a C_t value of 42 cycles. A C_t value of 42 cycles was determined by subtracting the minimum Ct from the maximum Ct for a given sample extract and plotting against C_t. Forty-two C_t corresponded to the lowest DNA concentration that could reliably be detected in both plant and soil replicates. For comparison, the limit of detection for a *Rhizoctonia solani* AG-3 real-time quantitative PCR assay was 168 fg of *R. solani* AG-3 DNA parts per billion (Lees et al. 2002).

Ease of Use

The real-time quantitative PCR with TaqMan® probes is easy to perform. Grinding of plant material under liquid nitrogen is the most time consuming step in sample processing. One set of 42 samples can be prepared by one individual during an 8-hour period. Furthermore, DNA isolation from plant and soil samples was simplified by using commercial kits. The kit for soil DNA extraction does not require special sample vials nor a bead beater; only a vortexer and centrifuge are necessary. Real-time PCR assays require about 3 hours of cycle time, approximately half the time of conventional PCR assays, not including post-amplification processing.

Assay Reproducibility

The reproducibility of the assay was determined by comparing values of replicate analyses (n=2) for 149 plant and for 147 soil samples. The plant samples had a smaller standard deviation average, 0.29 real-time PCR cycle (C_t), than the soil samples, 0.54 C_t. The deviations between replicate measurements using the real-time PCR assays are less than one cycle. Previous real-time quantitative PCR studies have established that duplicate assays are a sufficient number of replications for the quantification of target DNA (Lees et al. 2002; Winton et al. 2002).

Spatial Distribution of the Pathogen in Soil and Plant Crown Tissue for 8 Cultivars

Real-time PCR with TaqMan® chemistry was used to determine if levels of *O. herpotricha* infection correlated with the resistance and susceptibility of 8 cultivars of bermudagrass. In this study, according to Dr. Dennis Martin's unpublished data, the most resistant cultivar was OKC19-9 followed by Patriot, Mirage, Tifway, Sydney, Numex Sahara, Pyramid, and Princess. Other studies show similar but not identical disease ratings for these cultivars (Morris 2002). *O. herpotricha* was detected in 19 of 23 soil samples and in 2 of 24 plant samples (n=3).

Even though there were measurable levels of *O. herpotricha* in most soil samples, the crown tissue of bermudagrasses did not display disease symptoms during the November collection of turf plugs. This finding is in agreement with the small number of positives in plant material. It has been proposed that *O. herpotricha* hyphae are dormant during summer and winter, but actively colonize bermudagrass during spring and autumn when soil temperatures range from 10-25 °C (Fermanian et al. 2003). Our observations and measurements are inconsistent with extensive pathogen colonization of plant tissues

at the time turf plugs were removed from the turf plot. Future studies might resolve the timing of pathogen colonization of plant tissues by applying real-time PCR to measure *O. herpotricha* levels throughout the year.

Spatial Distribution of the Pathogen in Plots of Resistant Midlawn and Susceptible Greg Norman-1 Cultivars

We documented the spatial distribution of *O. herpotricha* in plant and soil samples of 2 infected cultivars of bermudagrass, susceptible GN-1 and resistant Midlawn (n=3) to demonstrate the feasibility of using the real-time PCR assay in this and similar epidemiological studies.

The GN-1 Plot A had the highest overall levels of *O. herpotricha* DNA of all the GN-1 and Midlawn plots. This coincides with the fact that the GN-1 Plot A had three widely overlapping dead spots in April 2001, and had the highest visible infection area relative to all other plots. The high levels of pathogen in GN-1 Plot A plant extracts stand in contrast to those in all other cultivars and plots. Either the pathogen is extensively colonizing these plants during autumn, or the spring infection has persisted through the dormant summer season.

The Midlawn plant extracts contained lower readings of *O. herpotricha* than those of GN-1 plant extracts though the readings were not significantly different from each other. The soil readings did not vary greatly between the two cultivars. Midlawn is resistant to *O. herpotricha* and this may explain the lower readings of *O. herpotricha* in Midlawn plant extracts compared to GN-1 plant extracts. GN-1 is susceptible to infection but there is no evidence to support that different cultivars support different soil levels of *O. herpotricha*. Further experimentation is necessary to resolve this issue.

The concentrations of *O. herpotricha* DNA from all samples revealed a patchy distribution in all three GN-1 and Midlawn plots. Up until now, little was known about the distribution of *Ophiosphaerella* spp. in soils throughout the season. Extrapolation from behavior of other soil fungi may not shed light onto the behavior of *Ophiosphaerella* spp either. Harris et al. (2003) found *Rhizoctonia solani* hyphae increased in density with increasing bulk density of soil, though they did not study any other soil parameters. Goodman and Trofymow (1998) found the abundance of ectomycorrhizae in mature and old-growth stands of Douglas-fir was related to soil chemistry. The distribution of fungi in southern Ohio hardwood forest soils was related to long-term moisture patterns in the soil and soil texture (Morris and Boerner 1999). However, Frey et al. (1999) found the fungal biomass in conventional and no-tillage agroecosystems along two climatic gradients was not strongly influenced by soil texture, pH, aggregation, organic C and N levels, or climate gradient effects, but positively related to soil moisture. These studies emphasize the need to determine the microscale patterns and the biotic and abiotic influences on fungal distribution for individual or small groupings of fungi.

The extreme variability found in this study of real-time PCR detectable DNA of *O. herpotricha* suggests an alternative sampling strategy. Many more samples than the number used in this study are necessary to make statistically relevant comparisons among treatments. Since the variation may be due to the patchy distribution of the fungus in the plots, it may be necessary to collect many more samples and analyze the prevalence of the DNA in terms of frequency of PCR positives. This would enable one to use standard PCR and simple agarose gel electrophoresis. On the other hand the use of real-time PCR

in such a system will allow quantitation of *O. herpotricha* DNA for each treatment, adding additional information for statistical comparisons.

CONCLUSION

We have developed a standard-curve real-time quantitative PCR assay with TaqMan® chemistry to identify and quantify the DNA levels of *O. herpotricha* in plant and soil samples. Theoretically the real-time PCR assay can detect 4 strains of *O. herpotricha* and one strain of *O. narmari*. The assay could not detect *R. solani* nor *P. arrhenomenes* genomic DNA. The plant total DNA extract was assayed directly and the soil total DNA extract needed dilution to 100 X and the addition of PVP. This assay is quantitative, sensitive, selective, rapid, and easy to perform. This powerful assay, which facilitates assessment of fungal prevalence, distribution and diversity, will be useful in the study of other plant diseases.

Table 22. Nucleotide sequences of the ITS region (Tisserat et al. 1994) showing (A) positions of the primers and TaqMan® probe within the *O. herpotricha* U04861 sequence, and BLAST alignments with the most closely related database entries for (B) the forward primer, (C) the reverse primer complement, and (D) the TaqMan® probe.

(A)

Forward primer — TaqMan® probe

```
5′ gtaggtgaacctgcggaaggatcattacacgatagtacaggccccaagtgtagaacaa
```

Reverse primer

```
actacgcagacgggttatgtctattaccttg 3′
```

(B)
Forward primer BLAST Match

Database Entry	DNA Sequence (5' to 3' + strand)
O. herpotricha (U04861)¶	tgaacctgcggaaggatca
O. korrae (U04862)	tgaacctgcggaaggatca

¶This sequence was used as the forward primer

(C)
Reverse primer BLAST match

Database Entry	DNA Sequence (5' to 3' + strand)
O. herpotricha (U04861)§	ctacgcagacgggttatgtctattac
O. herpotricha (AF101795)	ctacgcagacgggttatgtctattac
O. narmari (AF101798)	**actatgc**gacgggttatgtctattac
O. narmari (AF101803)	cta**t**gc**g**gacggg**c**tatgtctattac
O. korrae (U04862)	**act**c**atg**g**g**cgggttatgtctattac
O. korrae (AF101792)	ct**gtatg**g**g**cgggttatgtctattac
L. korrae (AF86626)	ct**gtatg**g**gt**gggttatgtctattac
	* *** **********

§ This sequence was used to produce the reverse primer

(D)
TaqMan® probe BLAST match

Database Entry	DNA Sequence (5' to 3' + strand)
TaqMan® probe	**acacgatagtacaggccccaagtgtagaacaa**
O. herpotricha (U04861)#	acacgatagtacaggccccaagtgtagaacaa
O. herpotricha (AF101795)	-cagcatagtacaggccccaagtgtagaacaa
O. narmari (AF101798)	-cacgatagtacaggccccaagtgtagaacaa
O. narmari (AF101803)	-cacgatagtacaggccccaag**c**gtagaacaa
O. korrae (U04862)	acacgatagtacaggccccaagtg**c**ag**c**acaa
O. korrae (AF101792)	-cacgatagtacaggccccaagtg**c**ag**c**acaa
L. korrae (AF486626)	acacgatagt**t**caggccccaagtg**c**ag**c**acaa
#TaqMan probe sequence	********* ********** * ** ****

Table 23. Mean threshold cycle values (C_t) and total DNA quantities from duplicate real-time quantitative PCR measurements of *O. herpotricha* DNA extracted from Greg Norman-1 Plot A plant and soil samples with and without spikes of 1 ng *O. herpotricha* DNA. Values demonstrate the extent of assay inhibition by matrix constituents and the effects of extract dilution and addition of 0.8% polyvinylpyrrolidinone (PVP) to PCR reaction mixtures. ND = not detectable.

Plant Samples

	Mean C_t (no spike)	Measured DNA in extract (ng)	Mean C_t (1 ng DNA spike)	Measured DNA in spiked extract (ng)
Description				
Plant extract 1X, no PVP	33.0	9.7×10^{-4}	20.9	9.5×10^{-1}
Plant extract 1X, with PVP	37.4	7.7×10^{-5}	21.5	6.8×10^{-1}
Plant extract 0.1X, no PVP	39.7	2.1×10^{-5}	21.8	5.7×10^{-1}
Plant extract 0.1X, with PVP	41.9	5.8×10^{-6}	21.7	6.1×10^{-1}

Soil Samples

	Mean C_t (no spike)	Measured DNA in extract (ng)	Mean C_t (1 ng DNA spike)	Measured DNA in spiked extract (ng)
Description				
Soil extract 1X, no PVP	44.0	ND	45.0	ND
Soil extract 1X, with PVP	44.0	ND	44.0	ND
Soil extract 0.1X, no PVP	45.0	ND	23.1	2.7×10^{-1}
Soil extract 0.1X, with PVP	44.0	ND	23.1	2.7×10^{-1}
Soil extract 0.01X, no PVP	45.0	ND	23.0	2.9×10^{-1}
Soil extract 0.01X, with PVP	44.0	ND	23.8	1.8×10^{-1}

Table 24. *O. herpotricha* DNA concentrations (ng DNA g^{-1} sample) for plant and soil samples from 8 cultivars differing in resistance to infection. Values are means of duplicate determinations.

Cultivar	Field Spot Area*	Rep 1		Rep 2		Rep 3		Average	
		Plant	Soil	Plant	Soil	Plant	Soil	Plant	Soil
	cm^2	*ng DNA*							
Princess	2995	0.0	1.3	0.0	1.2	21.0	0.1	7.0	0.9
Pyramid	2132	0.0	0.3	0.3	1.7	0.0	0.0	0.1	0.7
Numex Sahara	1589	0.0	1.0	0.0	0.0	0.0	2.8	0.0	1.3
Sydney (SW1-7)	1578	0.0	0.1	0.0	1.7	0.0	1.6	0.0	1.1
Tifway	1452	0.0	0.8	0.0	5.6	0.0	2.4	0.0	2.9
Mirage	1432	0.0	1.0	0.0	1.7	0.0	0.2	0.0	1.0
Patriot	632	0.0	0.4	0.0	0.0	0.0	0.5	0.0	0.3
OKC 19-9	210	0.0	#	0.0	2.2	0.0	0.0	0.0	1.1

* Field data collected by Dr. Dennis Martin of the OSU Horticulture Department from 2000 to 2002. The higher the number the more susceptible the cultivar.
# Sample was lost during storage, and not analyzed.

Table 25. *O. herpotricha* DNA concentrations (ng DNA g^{-1} sample) for Midlawn plant and soil samples. Values are means of duplicate C_t determinations. 0.0 = non-detect. - = no sample. *O. herpotricha* DNA in the periphery was significantly different from other means (p=0.017)

Location	**A Plot**		**B Plot**		**C Plot**		**Average± Stdev**	
	Plant	**Soil**	**Plant**	**Soil**	**Plant**	**Soil**	**Plant**	**Soil**
	ng DNA g^{-1} sample							
Center	0.1	0.3	0.1	0.1	0.0	0.3	**0.1 ± 0.05**	**0.9 ± 1.24**
	0.1	2.7	-	-	-	-		
Center Plot Averages	**0.1**	**1.5**	**0.1**	**0.1**	**0.0**	**0.3**		
Periphery	0.1	0.3	0.1	0.1	0.0	8.9		
	0.1	0.9	0.0	0.1	680	3.0		
	0.2	3.7	0.0	0.1	0.0	0.1	**56.7 ± 1.96**	**1.6 ± 2.60**
	0.1	1.8	0.0	0.1	0.0	0.5		
Periphery Plot Averages	**0.1**	**1.7**	**0.0**	**0.1**	**170.0**	**3.1**		
20 cm from Periphery	0.1	0.1	0.0	0.1	0.0	0.0		
	0.1	0.1	0.0	0.0	0.0	0.0		
	0.0	0.1	0.0	0.0	0.0	0.0		
	0.0	0.1	0.0	0.1	0.0	0.0		
	0.0	0.1	0.0	0.1	0.0	0.0		
	0.1	0.1	0.0	0.1	0.0	0.0		
	0.1	0.1	0.0	0.1	0.0	0.0		
	0.1	0.1	0.0	1.7	0.0	0.0	**0.0 ± 0.04**	**0.1 ± 0.34**
			-	-	-	-		
20 cm Plot Averages	**0.1**	**0.1**	**0.0**	**0.3**	**0.0**	**0.0**		
41 cm for Periphery	0.1	0.1	0.0	0.0	0.0	0.0		
	0.0	0.1	0.0	0.0	0.0	0.0		
	0.1	0.1	-	-	0.0	0.1		
	0.0	0.1	-	-	0.0	0.1		
	0.1	0.1	-	-	0.0	0.0		
	0.1	0.1	0.0		0.0	0.0		
	0.1	0.1	0.0	0.0	0.0	0.0	**0.0 ± 0.04**	**0.0 ± 0.05**
	0.0	0.1	0.0	0.0	0.0	0.0		
41 cm Plot Averages	**0.1**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**		
Overall Plot Averages	**0.1**	**0.5**	**0.0**	**0.2**	**32.4**	**0.6**	**14.2**	**0.7**

Table 26. *O. herpotricha* DNA concentrations (ng DNA g^{-1} sample) for Greg Norman-1 plant and soil samples. Values are means of duplicate C_t determinations. 0.0 = non-detect,. - = no sample. There were no statistically observable differences among locations or plots.

Location	A Plot		B Plot		C Plot		Average ± Stdev	
	Plant	Soil	Plant	Soil	Plant	Soil	Plant	Soil
	ng DNA g^{-1} sample							
Center	7.4	0.2	0.0	0.0	7.9	0.5	**67.6 ± 158**	**0.8 ± 1.2**
	390.0	0.9	0.0	0.0	0.0	3.2		
Center Plot Averages	**198.7**	**0.6**	**0.0**	**0.0**	**4.0**	**1.9**		
Periphery	270.0	0.1	0.0	0.0	0.1	0.7		
	180.0	0.4	0.3	0.0	0.0	0.3		
	240.0	1.2	0.0	0.0	150.0	1.0	**92.5 ± 119**	**0.8 ± 1.3**
	270.0	4.6	0.0	0.0	0.0	1.2		
Periphery Plot Averages Averages	**240.0**	**1.6**	**0.1**	**0.0**	**37.5**	**0.8**		
20 cm from Periphery	0.1	0.3	0.0	0.0	0.1	0.1		
	0.1	0.0	0.0	0.0	0.1	0.1		
	36.0	0.1	0.0	0.0	5.7	1.0		
	6.7	0.0	0.0	0.0	0.0	0.7		
	-	-	0.0	0.0	0.2	0.1		
	12.0	1.5	0.1	0.0	0.1	1.3		
	170.0	0.0	0.0	0.0	0.1	1.2		
	0.0	0.0	0.0	0.0	0.1	0.9	**17.4 ± 49**	**0.3 ± 0.5**
	170.0	0.0	-	-	-	-		
20 cm Plot Averages	**49.4**	**0.2**	**0.0**	**0.0**	**0.9**	**0.7**		
41 cm for Periphery	-	-	0.0	0.0	0.1	0.1		
	0.0	0.0	21.0	0.0	0.1	0.7		
	0.0	0.0	0.0	0.0	0.1	1.6		
	84.0	2.0	0.0	0.0	0.2	3.0		
	-	-	4.3	0.0	0.1	0.1		
	0.1	0.0	0.0	0.0	0.1	0.1		
	0.0	0.1	0.0	0.0	0.1	0.1	**7.4 ± 21**	**0.4 ± 0.8**
	53.0	0.0	0.0	0.0	0.1	0.1		
41 cm Plot Averages	**22.9**	**0.4**	**3.2**	**0.0**	**0.1**	**0.7**		
Overall Plot Averages	**94.5**	**0.6**	**1.2**	**0.0**	**7.9**	**0.8**	**46.2**	**0.6**

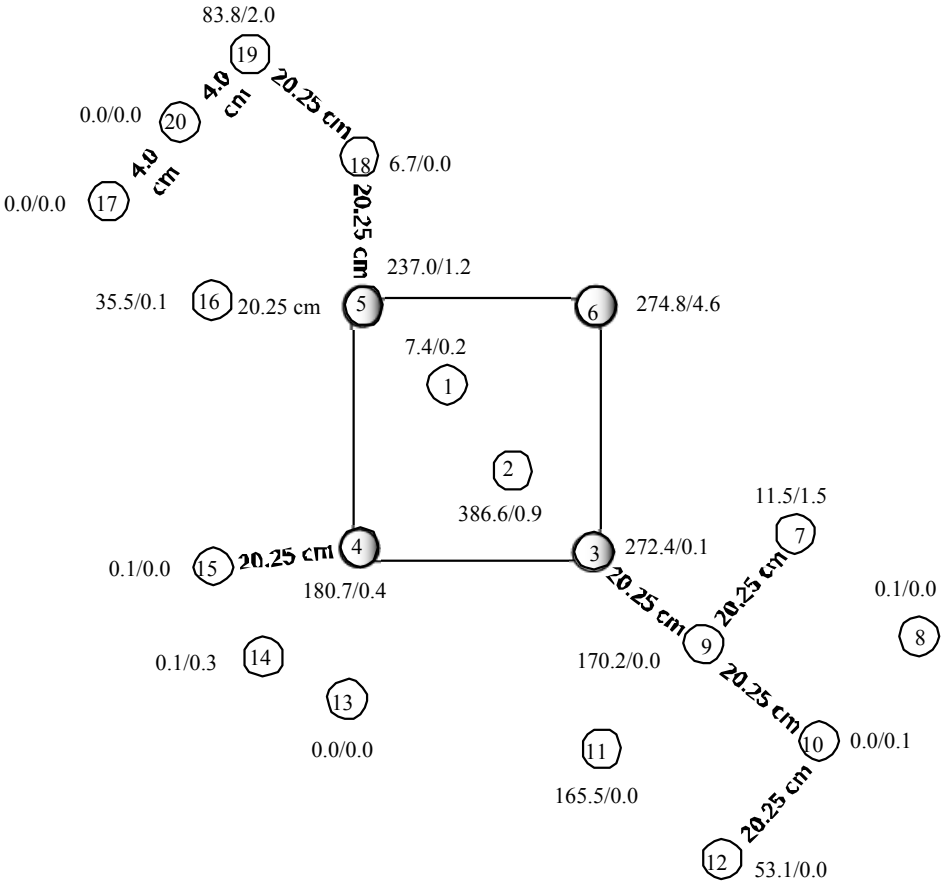


Figure 7. The location of 2.5 cm diameter plugs in the Greg Norman-1 Plot A. The dead spot is indicated by the square and measured 24.25 cm North to South and 22.25 cm West to East. North is at the top. The three dead spots in Plot A merged into one another, hence the odd shape of the dead spot and the unusual placement of the plugs. The plugs radiated from the edge of the dead spot and other plugs in 20.25 cm increments, except plugs 17, 20, and 19. The values are plant/soil ng of *O. herpotricha* DNA/g sample.

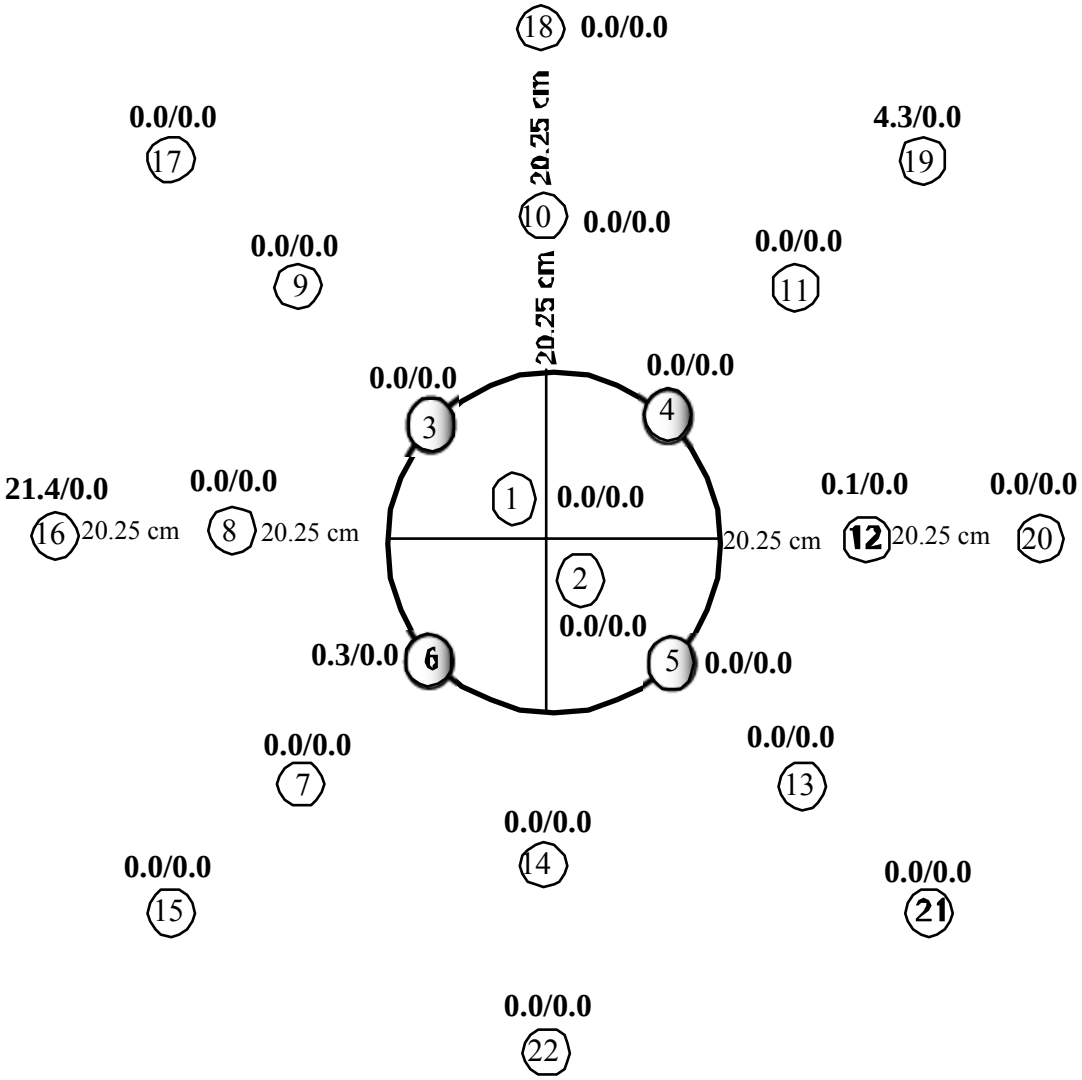


Figure 8. The location of 2.5 cm plugs in the Greg Norman-1 Plot B. The dead spot is indicated by the circle and measured 19.0 cm North to South and 22.25 cm West to East. North is at the top. The plugs radiated from the edge of the dead spot in 20.25 cm increments. The values are plant/soil ng of *O. herpotricha* DNA/g sample.

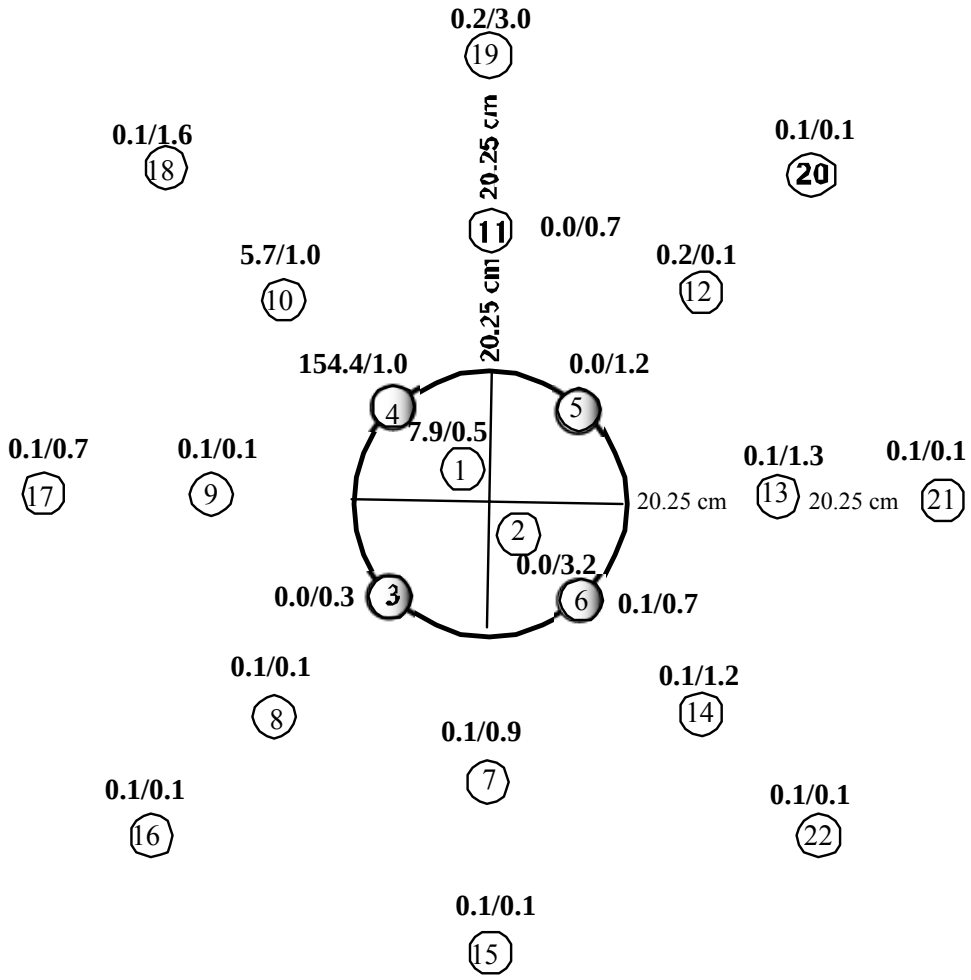


Figure 9. The location of 2.5 cm plugs in the Greg Norman-1 Plot C. The dead spot is indicated by the circle and measured 20.5 cm North to South and 20.0 cm West to East. North is at the top. The plugs radiated from the edge of the dead spot in 20.25 cm increments. The values are plant/soil ng of *O. herpotricha* DNA/g sample.

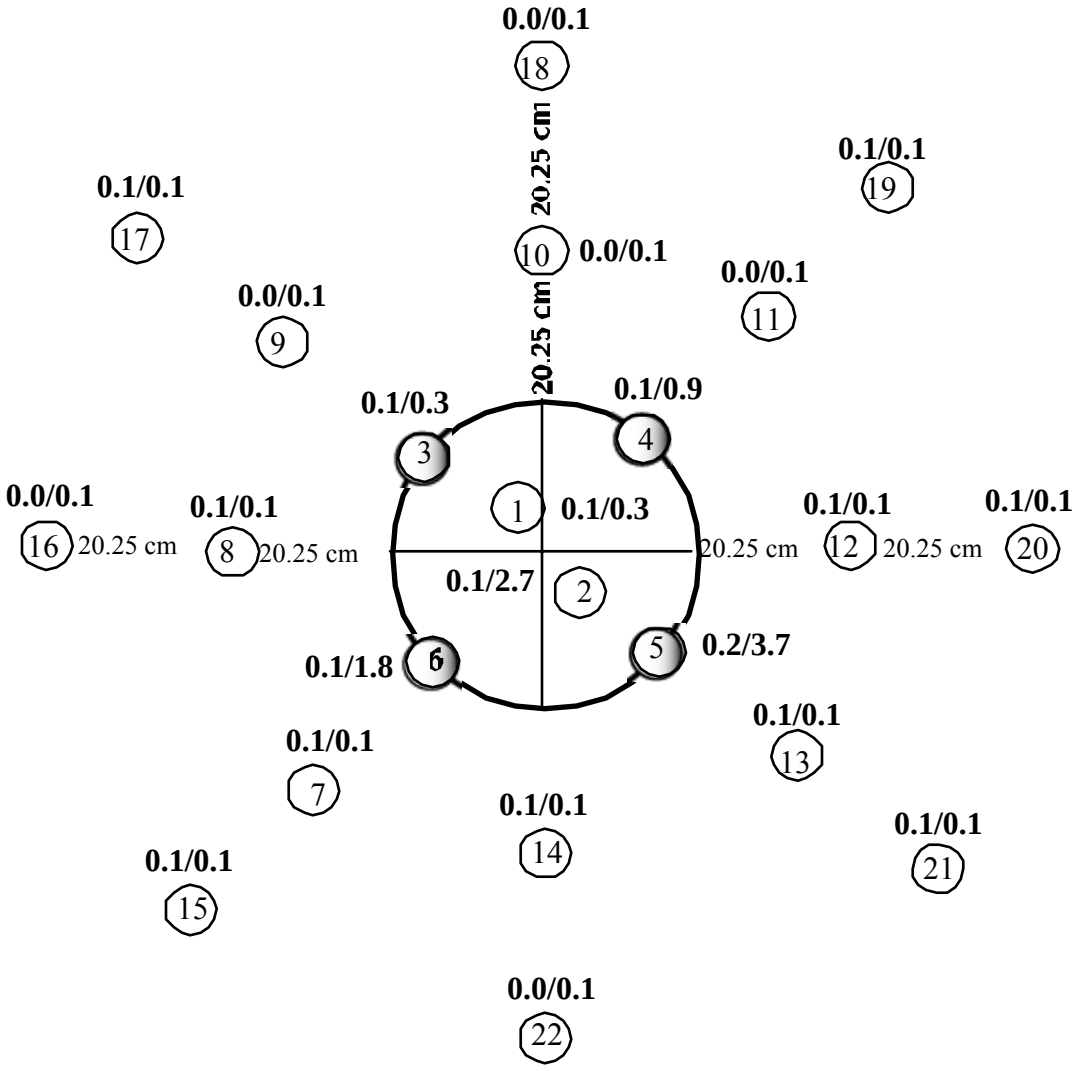


Figure 10. The location of 2.5 cm plugs in the Midlawn Plot A. The dead spot is indicated by the circle and measured 3.75 cm North to South and 3.5 cm West to East. North is at the top. The plugs radiated from the edge of the dead spot in 20.25 cm increments. The values are plant/soil ng of *O. herpotricha* DNA/g sample.

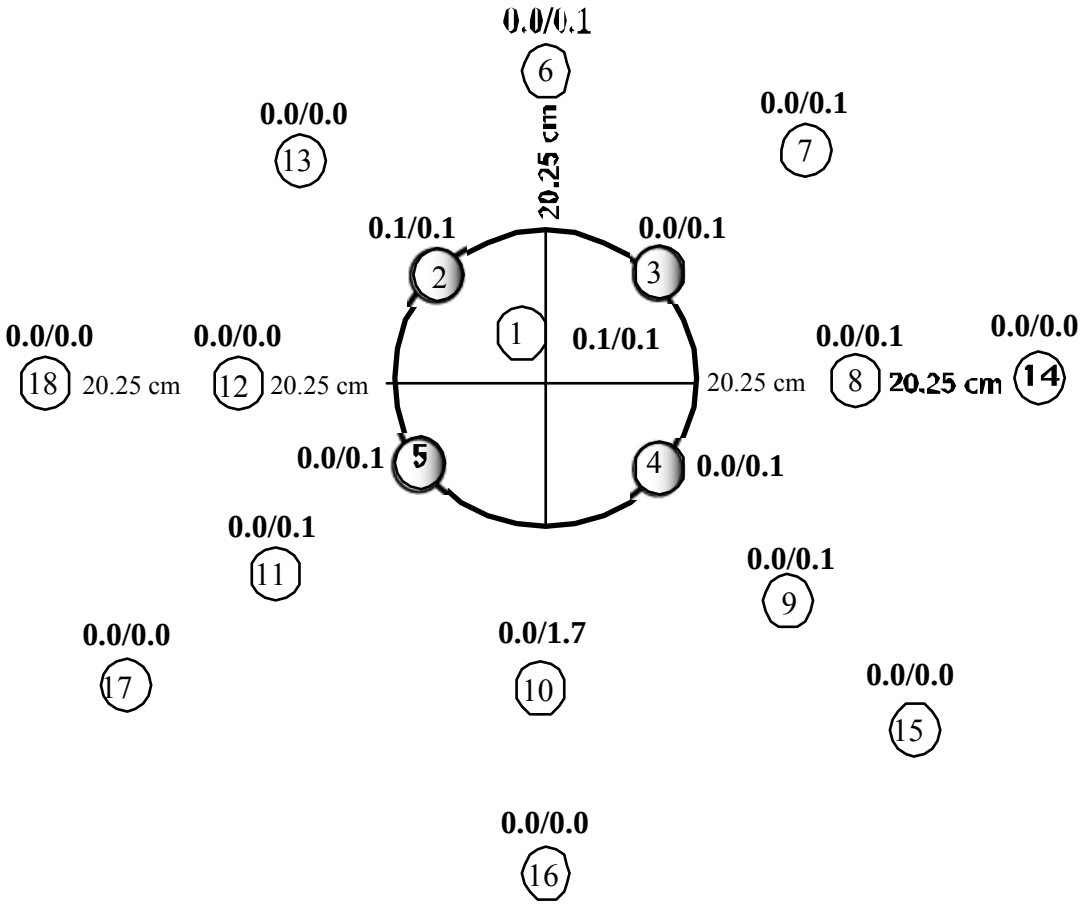


Figure 11. The location of 2.5 cm plugs in the Midlawn Plot B. The distribution of the plugs was influenced by the edge of the plot near the number six plug. The dead spot is indicated by the circle and measured 5.5 cm North to South and 3.25 cm West to East. North is at the top. Only one 1-inch plug was removed from the center of the small dead spot. The plugs radiated from the edge of the dead spot in 20.25 cm increments. The values are plant/soil ng of *O. herpotricha* DNA/g sample.

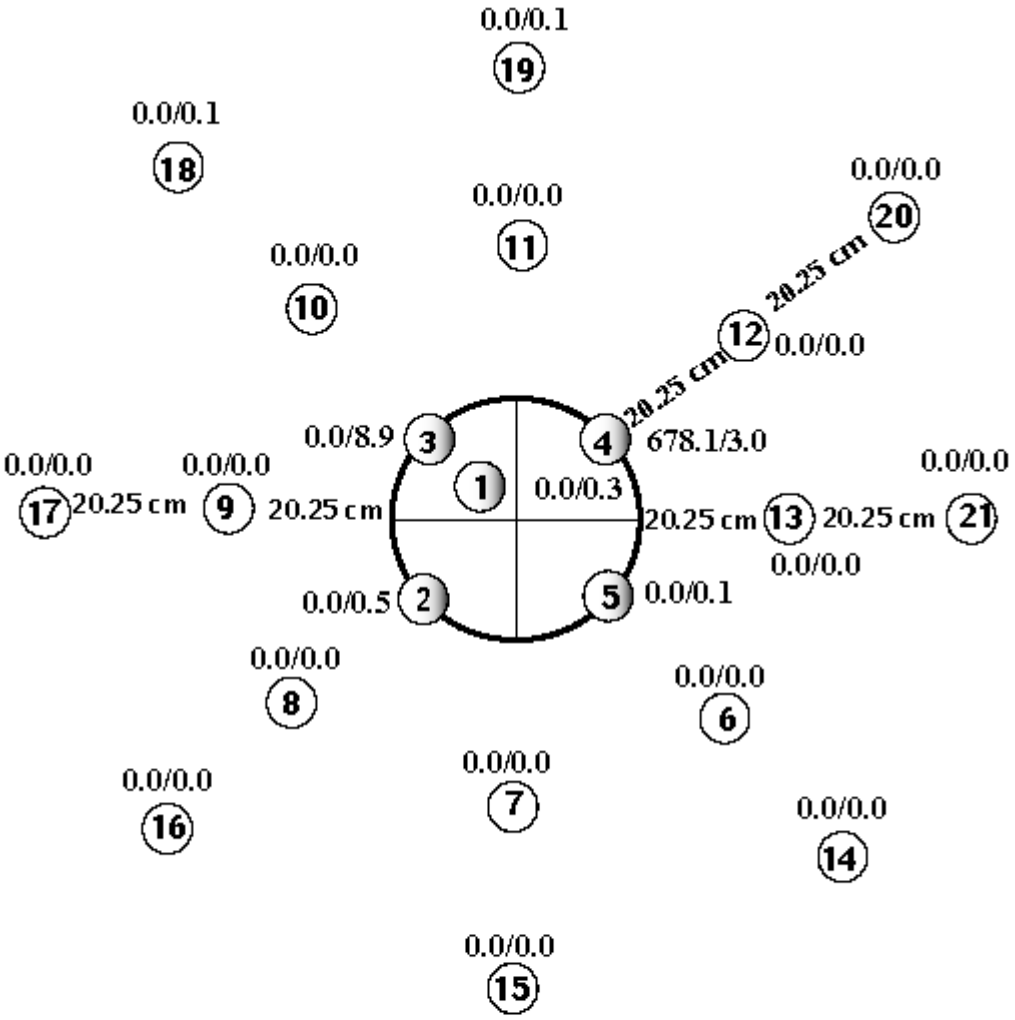


Figure 12. The location of 2.5 cm plugs in the Midlawn Plot C. The dead spot is indicated by the circle and measured 4.75 cm from North to South and 6.0 cm West to East. North is located at the top. Only one 1-inch plug was removed from the center of the small dead spot. The plugs radiated from the edge of the dead spot in 20.25 cm increments. The values are plant/soil ng of *O. herpotricha* DNA/g sample.

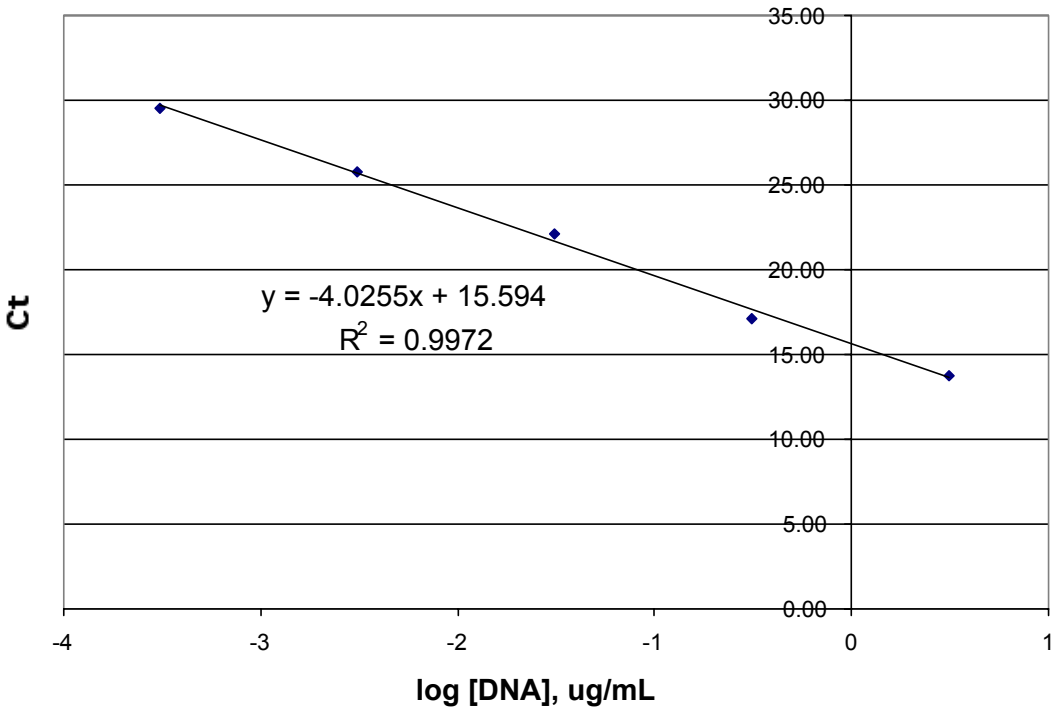


Figure 13. The standard curve of *O. herpotricha* genomic DNA, showing the relationship between DNA concentration and threshold cycle number (C_t).

BIBILIOGRAPHY

Applied Biosystems (2005). Essentials of Real-Time PCR. p 8.

Applied Boisystems (2002). Designing TaqMan® MGB probe and primer sets for gene expression using Primer Express® software version 2.0. p 25.

Altschul, S. F., T. L. Madden, et al. (1997). "Gapped BLAST and PSI-BLAST: a new generation of protein database search programs." Nucleic Acids Res. 25: 3389-3402.

Atkins, S. D., I. M. Clark, et al. (2003). "Detection and quantification of *Plectosphaerella cucumerina* a potential biological control agent of potato cyst nematodes by using conventional PCR, real-time PCR, selective media, and baiting." Applied and Environmental Microbiology 69(8): 4788-4793.

Baird, J. H., D. L. Martin, C. M. Taliaferro, M. E. Payton, N. A. Tisserat (1998). "Bermudagrass resistance to spring dead spot caused by *Ophiosphaerella herpotricha*." Plant Disease. 82: 771- 774.

Bassler, H. A., S. J. A. Flood, et al. (1995). "Use of a fluorogenic probe in a PCR-based assay for the detection of *Listeria monocytogenes*." App. Environ. Microbiol. 61(10): 3724-3728.

Bleicher, K. B., T. R. Pippert, W. E. Glaab, T. R. Skopek, J. F. Sina, D. R. Umbenhaurer (2001). "Use of real-time gene-specific polymerase chain reaction to measure RNA expression of three family members of rat cytochrome P450 4A." J. Biochem. Molecular Toxicology. 15: 133-142.

Bohm, J., A. Hahn, et al. (1999). "Real-time quantitative PCR: DNA determination in isolated spores of the mycorrhizal fungus *Glomus mosseae* and monitoring of *Phytophthora infestans* and *Phytophthora citricola* in their respective host plants." Journal of Phytopathology 147: 409-416.

Bustin, S. A. and T. Nolann. (2004). Primers and Probes. In A-Z of Quantitative PCR. Ed. S. A. Bustin. International University Line. La Jolla, CA.

Chen, S., A. Yee, et al. (1997). "The evaluation of a fluorogenic polymerase chain reaction assay for the detection of *Salmonella* species in food commodities." Int. J. Food Microbiol. 35: 239-250.

Crahay, J. N., P. H. Dernoeden, et al. (1988). "Growth and pathogenicity of *Leptosphaeria korrae* in bermudagrass." Plant Disease 72(11): 945-949.

Cullen, D. W., A. K. Lees, et al. (2001). "Conventional PCR and real-time quantitative PCR detection of *Helminthosporium solani* in soil and on potato tubers." Eur. J. Plant Pathol. 107: 387-398.

Cullen, D. W., A. K. Lees, et al. (2002). "Detection of *Colletotrichum coccodes* from soil and potato tubers by conventional and quantitative real-time PCR." Plant Pathol. 51: 281-292.

Duble, R. L. (1996). Turfgrasses: Their Management and Use in the Southern Zone. Texas A & M University Press. College Station, TX.

Endo, R. M., D. H. Ohr, et al. (1985). "*Leptosphaeria korrae*, a cause of the spring dead spot disease of bermudagrass in California." Plant Disease 69: 235-237.
Fermanian, T. W., M. C. Shurtleff, et al. (2003). Controlling Turfgrass Pests. Upper Saddle River, New Jersey, Prentice Hall.
Frey, S. D., E. T. Elliott, et al. (1999). "Bacterial and fungal abundance and biomass in conventional and no-tillage agroecosystems along two climatic gradients." Soil Biol. Biochem. 31(4): 573-585.
Goodman, D. M. and J. A. Trofymow (1998). "Distribution of ectomycorrhizas in micro-habitats in mature and old-growth stands of Douglas-fir on southeastern Vancouver Island." Soil Biol. Biochem. 30(14): 2127-2138.
Harris, K., I. M. Young, et al. (2003). "Effect of bulk density on the spatial organisation of the fungus *Rhizoctonia solani* in soil." FEMS Microbiol. Ecol. 44(1): 45-56.
Keirle, M., D. E. Hemmes, et al. (2003). "Monograph of the genus *Coprinus sensu* lato of the Hawaiian Archipelago." Direct Submission to NCBI. www.ncbi.nlm.nih.gov.
Lees, A. K., D. W. Cullen, et al. (2002). "Development of conventional and quantitative real-time PCR assays for the detection and identification of *Rhizoctonia solani* AG-3 in potato and soil." Plant Pathol. 51: 293-302.
Mayer, Z., A. Bagnara, et al. (2003). "Quantification of the copy number of *nor*-1, a gene of the aflatoxin biosynthetic pathway by real-time PCR, and its correlation of the cfu of *Aspergillus flavus* in foods." International Journal of Food Microbiology 82(2): 143-151.
Morris, S. J. and R. E. J. Boerner (1999). "Spatial distribution of fungal and bacterial biomass in southern Ohio hardwood forest soils: scale dependency and landscape patterns." Soil Biol. Biochem. 31(6): 887-902.
Morris, K. (2002). "Final Report on the 1997-2001 National Bermudagrass Test. NTEP Report 2002-7." NTEP.org.
Mumford, R. A., K. Walsh, et al. (2000). "Detection of *Potato mop top virus* and *Tobacco rattle virus* using a multiplex real-time fluorescent reverse-transcription polymerase chain reaction assay." Phytopathology 90: 448-453.
Oliveira, A. C., M. A. Vallim, C. P. Semighini, W. L. Araujo, G. H. Goldman, M. A. Machado (2002). "Quantification of *Xylella fastidiosa* from citrus trees by real-time polymerase chain reaction assay." Phytopathology. 92(10): 1048-1054.
Oberst, R. D., M. P. Hays, et al. (1998). "PCR-based DNA amplification and presumptive detection of *Escherichia coli* O157:H7 with an internal fluorogenic probe and the 5' nuclease (TaqMan) assay." App. Environ. Microbiol. 64(9): 3389-3396.
SAS (2001). Version 8.2. SAS Institute, Cary, NC.
Schena, L., F. Nigro, et al. (2004). "Real-time quantitative PCR: a new technology to detect and study phytopathogenic and antagonistic fungi." European Journal of Plant Pathology 110: 893-908.
Schoen, C. D., D. Knoor, et al. (1996). "Detection of *potato leafroll virus* in dormant potato tubers by immunocapture and a fluorogenic 5' nuclease RT-PCR assay." Phytopathology 86: 993-999.
Tisserat, N. A., S. H. Hulbert, et al. (1991). "Identification of *Leptosphaeria korrae* by cloned DNA probes." Phytopathology 81: 917-921.

Tisserat, N. A., S. H. Hulbert, et al. (1994). "Selective amplification of rDNA internal transcribed spacer regions to detect *Ophiosphaerella korrae* and *O. herpotricha*." Phytopathology 84: 478-482.

Tisserat, N. A., F. B. Iriarte, et al. (2003). "Identification, distribution, and aggressiveness of spring dead spot pathogens of bermudagrass." USGA Turfgrass and Environmental Research Online 2(20): 1-8.

Tisserat, N. A., F. B. Iriarte, H. C. Wetzell III, J. D. Fry, D. L. Martin. (2004). "Spring dead spot pathogens of bermudagrass." Golf Course Management. April: 177-120.

Tisserat, N. A., J. C. Pair, et al. (1989). "*Ophiosphaerella herpotricha*, a cause of spring dead spot of bermudagrass in Kansas." Plant Disease 73: 933-937.

Watschke, T. L., P. H. Dernoeden and D. J. Shetlar. (1995). Advances in Turfgrass Science: Managing Turfgrass Pests. Lewis Publishing. Boca Raton, NJ.

Wetzel III, H. C. et al. (1998). "Molecular evidence for the presence of *Ophiosphaerella narmari* n. comb., a cause of spring dead spot of bermudagrass, in North America." Mycol. Res. In Press.

Wetzel III, H. C., S. H. Hulbert, et al. (1999). "Molecular evidence for the presence of *Ophiosphaerella narmari* n. comb., a cause of spring dead spot of bermudagrass in North America." Mycol. Res. 103(8): 981-989.

Winton, L. M., J. K. Stone, et al. (2002). "Simultaneous one-tube quantification of host and pathogen DNA with real-time polymerase chain reaction." Phytopathology 92: 112-116.

Yun, J. C., K. G. Young, et al. (2003). "ITS sequence of *Phellinus* species." Direct Submission to NCBI. www.ncbi.nlm.nih.gov.

Zhang, Z. and G. Y. Yuen (1999). "Biological control of *Bipolaris sorokiniana* on tall fescue by *Stenotrophomonas maltophilia* strain C3." Phytopathology 89(0): 817-822.

APPENDIX

Appendix 1. Soil parameters of the bermudagrass cultivar plots at the Oklahoma State University Turfgrass Research Center, Stillwater, Oklahoma. The soil was analyzed at the Soil, Water, and Forage Analytical Laboratory, Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, OK.

Soil parameters:

Soil: Norge loam
Soil family: fine-silty, mixed, thermic udic paleustolls

Soil composition:

32.5 % sand
42.5 % silt
25.0 % clay

7.2 pH

Organic matter classification:

High levels, 3.1 % organic matter

Nutrients:

Surface nitrate 7.5 mg kg^{-1}
Surface sulfate 9.0 mg kg^{-1}
Magnesium 578.5 mg kg^{-1}
Biologically available potassium 62 mg kg^{-1}
Biologically available phosphate 300 mg kg^{-1}

Micronutrients:

Iron 53.3 ppm
Zinc 1.90 ppm
Boron 0.79 ppm

Appendix 2. The 16S rDNA contig sequences of the 225 culturable endophyte bacteria isolated from the crown tissue of Midlawn and Tifgreen cultivars of bermudagrass. The asterisks indicate where the sequences were truncated to produce high quality sequences for analyses.

Endophyte: 1
N***AGGGTGCAGCGTTTCCGGCATTTTGGGCGTAAAGAGCTCGTNNGCGGTTAGTCGNGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGG
TTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGG***NN
AATGTTGNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNN

Endophyte: 2
CCTNGGTCTGAGNGTTGNGTTGTTTTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGC
TCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAA
TGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGGTG
GGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTT
CCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGG
ACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAA
CGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGAATGT
TG***NCNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNTNNNNNNNNNN
TNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNTNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNNNTNTNN
NNNNNNNNNNNNNNNN

Endophyte: 3
GCTCNGTCGTGAGAAGTTGNCTCGNGTCGGGAAAGTNGGCTCGTGTGCGGAAANGTTGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGNGCGGTNGGGGAGATTGGAATTCCTGGTGTANCGGTG
GAATGCGCAGATNTCAGGAGGAACACCGATGGNAGAAGGCNGNATCTCTGGNCCGTNACTGACGCTGANGAGCGAAA
GGGTGGNGAGCNAACAGGCTTANATACCCTGGTATTCCACCNCANTNANTNTTNNGAACTATNTNNGGNNGACCNTNC
GNCCGGCACCGCNNNGACCGTTTCNTTNCCCCNTTTNNGTTTCCCNNNNCCTGNGNNNCCNCNGTNCGNTNANGNTNC
NNACCTNANNNNGAGANGGACCCNNGACCCNCGCNACCCGGANNCNNANTGCGNGNTTTTCNTTGATGAACACGCNN
AAAANCACTTNNCAAAGGCNTANTNTTATANCNNNAGCCCTTCTANNANACTGTTCANCTNTTATCGCANCANNNCNN
CNTANNATNGNNGCTNCNTNGGTNNCCNCNCTCANTNNCTTNNNANNTTCNNTNNCCCNTCCNATT***NNNNNNTNNN
CGCCTNGCCTNNNNACCAANNANGTTNNTAANTNAAANCNGCGNNGTCNNCNCGATATNCNCCGNCNGNATANCATN
NCNTCTNGCGNNNTCANNCCACNTCNTNCNGCCCATATNANCNCNNNNNNANCCANTACCTCGCCNNNANTCTNGNNN
CTCCNCCATGTTNNTAANATNNNACNNTTANNANNCNACAGCCNCNNNNAANTTANNTCNGNNNNANNAATGNANCC
CCCNCNNNNNTNTCNGCTNNANNNTANNN

Endophyte: 4
GTAGGCNCGGTCGNCGTTCGCTTNNCTGCNCGTAAAGGGCNCGNAGGCGGTNATTTAAGTCAGNTGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATTNGATACTGGCTAGNCTTGAGTNCTGGTAGAGGNGNNTGGAATTCCTNGTGTAGCGGT
GAAATGCGTAGATATNCGGAGGAACACCAATGGCGAAGGCNACCCNCTGGGCCNTTACTGACGCTGATGCTCGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACNCCGTAAACGATGNNNACTAGTTGTTGGGACCCTTNCNNT
TNTNTNNCGNNGCTTACGCCTTANNCNGTCCCCCTGGNGAGTACCGCCGCCAGNNTGAAACTNNAANGAATTGNCGGG
GGCCCCCNCNACCNGNGGANNATGTTGTTTAATTNTANGCNACNCCCAAAACCTTNCCNCCTTTTGNCATGCCNNGCA
NCCTTNAGANATANNNGTNTNCCTTTNNGGACACTGACACACAGGNNNTGCATGGTTGTCCACATCTCGTGTCGAGAN
ATGTTGGGTTAANCCCCNNAACGANCNCACCCCTTGNNTTATTTTCCNNCNACANGTGGGTGNTATCTTATGGCNNCCN
GCCNTGACAA***NNAGGAGGAGGGGGGGACNANNNCTNAATNATCCTTGNCCCTGGGGGNTCGGCCNCNTCNTCCTC
NGGTNCNCCNGNCNGNNGNCNCCNAANNGGGAAGGTANNCCANATCCCNNANGCNNTCNNGNNCNNNTNGNNGCTN
CCTCTNN

Endophyte: 5
TCNAACACGGTAGCCGTAAGCTTGGCNCCCGGGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCG
GGCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTG
AAATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTC
AGTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGG
ACCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATC
CTTTAGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGAT
GTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTGCCATTAGTTGCTACGAAAGGGCACTCTAATGGGACTGCCGGTGAC
AAACCGGAGGAAGGTGGGGATGACGTCAAGTCCTCATGGCCCTTATAGGTGGGGCTACACACGTCATACAATGGCTGG
TACAGANGGTTGCCAACCCGCGAGGGGGAGCTAATCCCATAAAGCCAGTCGTAGTCCGGATCCCAGTCTGCAACTCNA
CTGCGTGA

Endophyte: 6
AGNCNAACAGGTAGCCGTAAGCTTNNN***TTCCCGGGGAAAGGGCNCGTAGGCGGACTTTTAAGTCGGAGGTGAAAG
CCCAGGGCTCAACCNTGGAATTGCCTTCGATACTGGGAGTCTTGAGTTCGGAAGAGGTTGGTGGAACTGCGAGTGTAG
AGGTGAAATTCGTAGATATTCGCAAGAACACCGGTGGCGAAGGCNGGCCAACTGGTCCGAAACTGACGCTGAGGCGCG
AAAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGCCAGCCGTTGGGGAGCTT
GCTCTTCAGTGGCGCAGCTAACGCTTTAAGCATTCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTG
ACGGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCCTTTTGACATGT
CCGGTTTGATCGGCAGAGATGCCTTTCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGCCAGCCTCGT
GTCGTGAGATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTCGCCCCTAGTTGCCATCATTCAGTTGGGAACTCTAN
GGGGACTGCCGGTGATAA***NCCGCGAGGAANGTGGGGATGACCTCAAGTCCTNATGGCCCCTTACAGGCTGGGCTAC
ACACCTTGCTACAATGCCGGNGACAATGGGCAACCNAAAGGGCNACCNTCAACNTNTCCCCAAAAAGCCCCNNTNANT
TTANATTGCACTCTTGCAACTNGAGTGCNTNGAA

Endophyte: 7
GGAGGTGCAGCGTTATCCGGCTTTATTGGGTTTAAAGGGTCCGTAGGCGGATCTGTAAGTCAGTGGTGAAATCTCACAG
CTTAACTGTGAAACTGCCATTGATACTGCAGGTCTTGAGTAAGGTAGAAGTAGCTGGAATAAGTAGTGTAGCGGTGAA
ATGCATAGATATTACTTAGAACACCAATTGCGAAGGCAGGTTACTATGTCTTAACTGACGCTGATGGACGAAAGCGTG
GGGAGCGAACAGGATTAGATACCCTGGTAGTCCATGCCGTAAACGATGCTAACTCGTTTTTGGGTTTTCGGATTCAGAG
ACTAAGCGAAAGTGATAAGTTAGCCACCTGGGGAGTACGTTCGCAAGAATGAAACTCAAAGGAATTGACGGGGGCCC
GCACAAGCGGTGGATTATGTGGTTTAATTCGATGATACGCGAGGAACCTTACCAAGGCTTAAATGGGAAATTGATCGG
TTTANAAATAGACCTTNCCTTCGGGCAATTTTTCAAGGTGCTGCATGGTTGTCGTCAGCTCGTGTCGGGAAATA***NNT
TGGNNCCNNCACNNNNCNNNNNNCNNNNNGNGNNNNNANNNNNGNNNNCNNGNNNNNANNNNCNNNNGNNANNTG
NNNNGNCGNNNNNNNNGNNNNNNNNNGNNNNNNNNNNTNGNNNNNNNNNCCNTNNNCNNGNANGNNNNNNNNNAN
ANNCCCNNNNNGCGCNNNCNNGNNTNNCNNCNGNGNTNNNNANCNGNNNNNNTNNCCNCNNNNNCCNNCCCNNNNT
NTNGCNTNNGNCNCNCNGNNNNNNNNTANNNNCCGNGNNC

Endophyte: 8
GGANTTCAGCGTTNATCGGATTANTGGGCGTAAAGCGCACGCAGGCGGTCTGTTAAGTCAGATGTGAAATCCCCGGGC
TTAACCTGGGAACTGCATTTGAAACTGGCAGGCTTGAGTCTCGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAAA
TGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACGAAGACTGACGCTCANGTGCNAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTTCCCTTGAGGAGTG
GCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGG
CCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCCGAAGAACCTTACCTACTCTTGACATCCANAGAACT
TANCAGAGATGCTTTGGTGCCTTCNGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCANCTCGTGTCGGAAAAAGT
TGGC***NNCNCCCCNNNGCCCNNGGANATNNANANNNNGANNNNANNNAAGCCNGGNGNTANNNGTGNNTCNGAGT
GCNAAGGNNGANNCCGCNNNGGNTNCNCGNANGCCNGNAANGTNNTATNTCNGATTGCGCNNACANATNTCNCCCNC
GNGCAGTNNNNGACCNCGCNCGCACANCNCCANNCANANANNTCNGCCCNNCNNCTNCACNNNCNCGTNCNNNCAGN
NCGTNCGNGCCNACNCNNNCNNCNNGNCCGNNNCANCN

Endophyte: 9
TAGGGTGAAGCGTTAATGCGGAATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCG
GGCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTG
AAATGCGTAGATATGCGGAGGAACACCNGATGGCNGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAG
CGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGAC
TCAGTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGG
GACCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAAT
CCTTTAGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCG***NGN
AAAANTTTNGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 10
GGAGGGNGCNGNCGNNANTACGCNTTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTTAAGTCAGATGTGAAATCCCC
GGGCTTAACCTGGGAACTGCATTTGAAACTGGCAGGCTTGAGTCTCGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGT
GAAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACGAAGACTGACGCTCAGGTGCGAAAG
CGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTTCCCTTGAGG
AGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACG
GGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAG
AACTTAGCAGAGATGCTTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAAA
TGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTATCCTTTGTTGCCAGCGATTCGGTCGGGAACTCAAAGGAGACTGC
CGGTGATAAACCGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGAGTAGGGCTACACACGTGCTACAA
TGGCGCATACAAAGAGAAGCGACCTCGCGAGAGCAAGCGGACCTCACAAAGTGCGTCGTAGTCCGGATCGGAGTCTGC
AACTCGACTCCGTGAAGTC

Endophyte: 11
GNTNNTGCAGCGGGTANTNGGCATTACTGGGCGTAAAGCGTTNNCCAGGCGGGTGATAGTAAGTACAGATGTGAAATC
CCCGGGCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTTGGAGTACNGGCAGAGGGGGATGGAATTCCGCGTGTA
GCAGTGAAATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTTGACGCTCATGCAC
CGAAAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTT
CACCTGACTCAGTAACGAAGCTAACGCCGTGAAGTTGACCGCCTGGGGAGTACCGGCCGCAAGGTTGAAACTCAAAGG
AATTGACGGGNNCCCGCACAAGCGGTGGATGATGTNGTTTAATTCGATGC***AAAANGAAAAACCTTNTTNACCTTTG
NNATNNNCTTGAAAAACTTTAGGGGGGNGNNGAGAGNCCNAAAAAAAAAACCCCCCAAAANTTNCTCAATCTTTTTGG
GGGAAATTTNNNNNTTTTTTTTNNNAAACNTNTTTTTTNCNNNGNTTGNGNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTN

Endophyte: 12
TAGGGCGCAGCGTTTCCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCT
CAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAAT
GCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTGG
GGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTC
CGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAAC
GGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGAAAAATNTT
TGCC***NNNNCNNNCNNNNNNNNCNNCNTANNNAANATANNNNCGNNTTNNNNNNNNNTNNNANTTNTNNNCNNNN
NTNNNTTTNNNNNNANNNNTAANNNTCNTGNANNNNNANANAGNGANNGNNNNNNNNNNNNNNTNANNNNNNCNNN
NNTATNNTNNANNTNGCNNTNATANNNNNNNANNANCCNNNCNNNTNNNNNNNNTNNNANNNTNTNNTANNNCNNTT
TANNTTTNNNGNCN

Endophyte: 13
TAGGGTGCAGCGTTAATCGGATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCGGG
CTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGAA
ATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCAG
TAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGAC
CCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATCCT
TTANAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGAAAAAATG
TTNG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNANNNNNNNNNNNNCNNNN

Endophyte: 14
TACNNCACGGTNGNTCGTAAGGCTTGNCTNCNNGGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCC
CGGGCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAG
TGAAATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAG
CGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGAC
TCAGTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGG
GACCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAAT
CCTTTAGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGA
TGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTGCCATTANTTGCTACGAAAGGGCACTCTAATGGGACTGGCGGTGA
CAAACCGGAGGAAGGTGGGGATGACGTCAAGTCCTCATGGCCCTTATAGGTGGGGCTACACACGTCATACAATGGCTG
GTACAGAGGGTTGCCACCCCGCGAGGGGGAGCCTAATCCCATAAAGCCAGTCGTAGTCCCGGATCCGCAG***NCNTG

Endophyte: 15
CTCTGTCGTGAGANGTTGAGGATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGA
AATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCA
GTAACGAAGCTAACGCGTGAAGTTGACCGTCTGGGGAGTACNGCCNCNAGGTTGAAACTCAAAGGAATNGACGGGGA
CCCGCACAANCGGTGGATGATGTGGTTTAATTCNATGCANCGCNAAAAACCTTACCCNCCTNTNACATGNACGGAATN
CTTTNATAGATANACNATTGTTCCAAAGAATAACCTGTANCNACANGTGCTGCATGGNCTNCTNCNCANNCTC***NNN
TNNCCNNANTTTNCNTNNTCNNNCNNNCNANNNNACCCNANNTCTTNNNACNTCTANCCTNATCNNNCATNCNNATGN
NNTTNCCATCCNANNTNTCANTTCTTTCNNNCNNTNTTCNCCANCCNCCCNCCGNNCNGNCTATCANTCCTNNCANCCN
CANNNAANNNNCTGCACTNTNNCNNATTNNNTNNNTTTTATNTCTCNCNCTCCTNTTCTCNTACTNCAACANANNGNNC
NGNAACNCCGNTCCNANANNATCNNNCNANCNCNGNTACCNNTCGNNTATT

Endophyte: 16
CTCTGTCGTGAGCNGTTGACTNNNTTCTGGAAATTNGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGG
CTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAA
ATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGGCGT
GGCCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGG
GGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAGAA
CTTNNCAGAGATGNNTTGGTGCCTTCGGGAACTCTGANACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCG***NNCN
AANNNTTGANTTTTTCCTCCNNNNNCNTCAATNNNNCNCCCNCCNCTTTCNNTTTTTNATANCTNCNCNTNNCNNTNCN
CCNTTCNNCCNNTTTNTCNTNTTCCCCCNTCNNTNANCCCCNNCCCATCTTTCTNNCTTTCACCCCCCCTCNCCCTANNAT
CNNNNNTTACTNANATNNCTGCANNNTNCNNNTNTATTATNTNTTATCTCTTCNANTNNNNCNATNNNACCNCCANNC
NTANTNGTNTNNCCTACNNNTNNNNCNGNCTNNTANATCNN

Endophyte: 17
CTCNGTCCTGAGNTGTTGCGNATTATTGGGCGTAAAGGAGCTCGTATGCGGNTNGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGG
TTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCA***NCTCGTGTCGTGG
AAATGTTGCCNNNNNNTTNNCNTCNCNCNCNCTTNNTNNNCCCNNNTCCNTTANCTANTNTNNNATNACNNNTATCNN
NNTTNCCCCNTTTNCNNACCNNCNCNNNCANNNNNTNNCNCNNTNTTTNNTCNTNTCNTCCTTNCNCCNCNATNNNNNC
NNTNNNNCNNNCNCCCNTNTNNNNNANNNNANNCNNNNNTCTNNANANNNCNNCCCCNNTNTNNTNNNNCCNNTCNN
GCCCCNCATNNCNC

Endophyte: 18
TAGGGTGCAGCGTTAATCGGATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCGGG
CTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGAA
ATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCAG
TAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGAC
CCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATCCT
TTAGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGGNNAAAAT
GTTG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 19
TAGGGTGCAAGCGTTAATCGGATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGA
AATGCGTAGATATGCGGAGGAACACCNGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTC
AGTAACGAAGCTAACGCGTGAAGTTNACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGG
ACCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATC
CTTTAGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGGANAAA
AGTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 20
GGAGGTGCAGCGTTATCGGATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGGC
TCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAAA
TGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGGCGTG
GCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGG
CCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAGAACTT
NCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGNAAAAATGTT
GG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 21
CGCTCTGTCGTGAANNGTTGANNCATTATNGGGNGNANNNGAGCTCGTGNCGCGGNTTGTNGCGTCTGCTGTGAAATC
CCGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGC
GGTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGA
AAGGGTGGGGAGCAAACAGGCTTANATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTC
CACGGTTTCCGNGACGCAGCTAACGCATTAAGTTCCCCNCCTGGGGAGTACGGNCGCAANGCTAAAACTCAAAANGAA
TTGACGGGGACCCGCACAAGCGGCGGAGCATGCGGGATTAATTCNATNCNACCNCGAANAACCTNACCAANGCTTGAC
ATATACNNACAACGGGCCCAGAAATGGTCAANTTTTTGNATACTCCCTNAACNGGCNGGCNCNTGNTTGTNTTCNNNCT
NCTNTACNCGAGAATGTNTNNTTCTTCNNTT***NNNNCNTCNCCNCANTTNTNCCCNCCNNCNNNNCNCCTCNTNGTTT
TTNNNTNCCTANNNTNTCCGCCANNATCCCGATTTNGTAGNTNTNNCNCCNTAGACTNNTANANTTCNNNATNTNNNN
NCTANNTTNNNCTCNTNCCTCCTNNTNTANNANTTNNNTNNNATNCCCCCNGATCNTCATTNNAATTATNNNNNACTNA
NNCNNNTANNCTNCNNCCTNTCACAATTANNTTNCCCCNCNNNTNTAANCNNNNAATTTTANNT

Endophyte: 22
GGAGGTGCAGCGTTATCGGATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGGC
TCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAAA
TGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCNGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGGCGT
GGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGG
GCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAGAACT
TNCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGNAAAATTNT
TGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 23
CGAGCTCGTGTCGTGAGCAGTTGTTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGG
TTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGNAAN
TGTTG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 24
GGAGGTGCAGCGTTAATCGGATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGG
CTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAA
ATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGGCGT
GGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGG
GCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAGAACT
TNCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGNAAANATNT
GG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 25
CGAGNTCTGTCGTGANAGTTGN***TTTTGGCGTNAAGAGCTCGTACGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGANNGGGT
GGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGT
TTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGG
GGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAG
AACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGAAT
GTTG***NCCCNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNTNNNNNNNNNNNNNCNNNCTNNNNNTCNNN
NNNNNTNNNNNNANNNTTNNNNTNTNNNNCNCTCTNNNNTNNCNNNNNNCNTTNTNNNNNNCCNNCNANNNTNNNN
NNNNNNNNTNNNCNCNNNNNNCNNNNTATTNCNATCNNNNNCNNCNNCCTNNNNNNNNTNNNNTNNNNANNNNTTNN
NNNNNNTCNNNNNNN

Endophyte: 26
CTCNGTCGTGAGTGTTGANN***CATTTNGGGCGTAAAGGAGCTCGTANGCGGTTTGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGTCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTTACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACG
GATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACG
AGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATNTTTGTCGTCAGCTCGTGTCGT***NA
AANTGTTGNCNNNNCNNTNNCNTANNACANNNNNNNNNNNNNNTNNNCNNTCCNNNTNNTNNNNNNNNNNNNNNNN
NNNGNTNCNNNNTTNNTNNTCNGCNNNNNNNNNNTNNNNNNANCNNTTNTCNNNAGTNNNCNCNNTNNNNTANNANN
NNTCNTCNNNTNNNCANNGNNTTCNCNNNNTNNNNNNNNNNNTNCNNNTCNNNNCNTNANNNCTNNNANCNNCCCCC
NCNACNNCNNAATNNNNTNTN

Endophyte: 27
GCTCGGTTCGTGGNNATTTTGGATTCNGGTNCNGNAGTNTTNGCCNCGGGTCCGGNAATNTTGCCCCCGNNCCGGNNN
NTTTGCCCCCTNCCCGGNNNNTTTTCCCCCTCNCNGGNNATTTTNTCCCNANCNNCGGGNGANTNGTNTTTCNNTTGTN
GGAGNNGANTNCTTCCTNTATNACNGNGGNNNNCCGGNTGGGGGNAANGNTGTNNNATNGGNGCTGGGGACGTGCCC
CNTTTNCCNCCTATATNGNTTGATNTGAGNGGGGGGGGNCTGGNTNCATCNCNGGNNCGTTTGTGGNCNTNNTTNNGC
CNCTNNAANNTTAAACNNNGGGANGNCCNGNNGACCTTNTCTTTTNNCNNNTNNNNNTNTNTNNNTCGNANNTGCTAN
TNNCNNTGGANNATTCAGTCNNNNNATTCTNTANTCAGTTTATGNNGGNTTACNCNANGCNNNTNNNCNNNCNGTANG
NNNNGCGNCNGNGNGNTCNCCATNNNNNCNANTGTTNCCGGTANACNTANCNNTNNGNTNNNAGNGTTGTTCGNGTN
TTCNNTNTCGCGNNNCNGTTNNNATTNCATCTNCNANNTTNTANGCNNNGGGTCNGCGNCNCNTNCCNTGGNCTCCAN
NANCANGCCNNNNNANCCCGNNAATNNCNNTGTTTTNTNNNNNGNNNNNNGCCCATNGNNCCNNNNGCCTCCCNCNN
GNNGGCGNCNNATTTTNTNNGCGTTGNCNCNNNCTCCCCGCTNNNCNCCGATATTTNCTNNNGCNCNCNTTTNNCTCGN
NTNNNNTNTNNCNNTNTATATGTCNNNANTCCNNCCNTGCNNGTGTGTCCNTATNNCCNTCTCCNTCTTCGTANNNCGC
CGTANGNNNNNTTNANTATGTTNCNNCTCCGNCNGNTGNNTGCGCCNNCNNCNNNCCACCNNNNNNTATNTNTCGCCC
CACNTTNTNNCACANTNANTNATATNT

Endophyte: 28
CTCGGTCCNGAGNNATGCGGN***ATTTTGGGCGTAAAGAGCTCGTANGCGGNTNGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGTCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTTACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACG
GATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATNTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
GAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTG**
*NAANTGTTGGNCNNNNNNNNNNNNNATNNNNNNNTTNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNN
NNNNTCNCNNTTNNTNNNTTTNNNNNNNNNNNNNNNNNNNNNTNNNNNNNNNCNNNNNNNNNNNNANNNNCNNNNNN
NCCNNTNNNNNNNNNNNNNNNNNNCCNNNNNGNNNNNNNCTNNNNNTTNNNNNNNNNNNNNNCNNCCNNNNANN
NNNNNNNCCCNCCNCNCTNCCACNANNTNNNNN

Endophyte: 29
CTCNGTCCNGAGNGTTGCGGCATTATTGGGCGTAAAGAGCTCGTGTGCGGANATNTTGGTCTGCTGTGAAATNCCGAG
GCTCAACCTCGGGTCTGCAGTGGGTACGGGCAANACTAAGAGTGCGGTANGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCTGCAATATATCAGGAGGAACACCGGATGGCAAAGGCAGATNTNTGGGCCGTTACTGACGCTGAGGAGCGA
AAGGGTGGGGAGCAAACAGGCTTAAATACCCTGGTAGTCCACCCCGTAAACNTTGGGAACTANTTGTGGGGTCCATTC
CACGGATTCCGTGACGCAGCCTAACGCATTAAGTTCCCCGCCTGGGGAGTACNGCCGCAAGGCTAAAACTCAAAGGAA
TTGACGGGGACCCGCACAAGCGGCGGANCATGCGGATTAATTCGATGCAACGCGAANAACCTTACCAAGGCTTGACAT
ATACNAGAACGGGCCAAAAATGGTCAACTCTTTGGACACTCNTAAACAGGTGGNGCATGGTTGTCGTCANCTCGTGTC
GTGAAAAATGTTGAC***NNNNNNNNCNNNNNNNNNNNNNNNNNNNNNCNNNNNNNANNNNNNCNNNNTNNNNNN
NNNNNNNNNNNCNNNNNTNNNNNTNNNNNNNNNTTNNCNNNNNNNNNNNTNNNNNNNCNNNNNNNNNNNNNNN
NNNNNNNNNNATNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNTNNNNTNNNCN
NNNNNNNNNNNCNCNNNNNNNT

Endophyte: 30
GAGGTTGCAAGCGTTAATCGGAATTACTGGGCGTAAAGCGCGCGTAGGTGGTTCGTTAAGTTGGATGTGAAAGCCCCG
GGCTCAACCTGGGAACTGCATTCAAAACTGTCGAGCTAGAGTATGGTAGAGGGTGGTGGAATTTCCTGTGTAGCGGTG
AAATGCGTAGATATAGGAAGGAACACCAGTGGCGAAGGCGACCACCTGGACTGATACTGACACTGAGGTGCGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCAACTAGCCGTTGGGAGCCTTGAGCT
CTTAGTGGCGCAGCTAACGCATTAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGG
GGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGCCTTGACATCCAATGA
ACTTTCCAGAGATGGATTGGTGCCTTCGGGAGCATTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGNAGAAT
GTTTGTTTAT***NTTNNACCATTNTTNTCNTATNNCTTCNCCCCTNNNATNTNCNNCNTNNNANATACNCCCTNATNCC
CTTTNCTCCNATNTNTCTTTCNNCTNTNNTCTNTCTCNTTCNNTNNNNTNTNNNNCNACNTACCANCCNCCTCCCNTNNT
NCCTTTTCCTAGNNTANTATNNTATCGNNANTCNCNNNNCANCNCCCCNCTTCACNTACCTCNCCNTCCNTANCTNCCC
NCCTN

Endophyte: 31
N***GCTCTNTCGTGAAANNTTGANCCNTTTNNNGAGNANTGGCTCNGTANGCGGATTGTTNCNTCTGCTGCGAAATNC
CNAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCG
GTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAANAACCTTACCAAGGCTTGACATAT
ACGACAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTG
AGATGTTGNAT***NNNCNAANNCTNNNNACCACANTTCCCCCCCCNCCCNCANATNNTNCTTTTTCTTTNTNCNCCNTCC
NCCAGTNTNCCTANNTNTCNATTTCTANCNNANANCNCACTNTNCTCNCNCTNTCCNCNCTTNTTCCGNNNTGCCNCAN
ACCTNTCNTGTNANCNATNNNCCNCCANANCCNNCTNTNANTTTCTTNNTNCNNNTTNTCTANANTCATTCCTNTTANN
NTCCCCCTCNACNCCCCCCTTTATNCTCGN

Endophyte: 32
AAAGGTTNCTCGTAAGCTTTGGATCCCGGGGCGCGCGTAGGTGGTTCGTTAAGTTGGATGTGAAAGCCCCGGGCTCAAC
CTGGGAACTGCATTCAAAACTGTCGAGCTAGAGTATGGTAGAGGGTGGTGGAATTTCCTGTGTAGCGGTGAAATGCGT
AGATATAGGAAGGAACACCAGTGGCGAAGGCGACCACCTGGACTGATACTGACACTGAGGTGCGAAAGCGTGGGGAG
CAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCAACTAGCCGTTGGGAGCCTTGAGCTCTTAGTGGC
GCAGCTAACGCATTAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGGCCCGCA
CAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGCCTTGACATCCAATGAACTTTCCAG
AGATGGATTGGTGCCTTCGGGAGCATTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATGTTGGGTTA
AGTCCCGTAACGAGCGCAACCCTTGTCCTTAGTTACCAGCACGTTATGGTGGGCACTCTAAGGAGACTGCCGGTGACAA
ACCGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGGCCTGGGCTACACACGTGCTACAATGGTCGGTA
CAGAAGGTTTGCCAANCCGCGANGTGGAGCTAATCCCACAAAACCGATCGTATCCCGGATCGCAATCTGCAACTCGAC
TG

Endophyte: 33
TAGGGTCGCNGTNGTTCNTCGGCNTNACTGGGCGTAAAGCGCGCGTAGGTGGTTCGTTAAGTTGGATGTGAAAGCCCC
GGGCTCAACCTGGGAACTGCATTCAAAACTGTCGAGCTAGAGTATGGTAGAGGGTGGTGGAATTTCCTGTGTAGCGGT
GAAATGCGTAGATATAGGAAGGAACACCAGTGGCGAAGGCGACCACCTGGACTGATACTGACACTGAGGTGCGAAAG
CGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCAACTAGCCGTTGGGAGCCTTGAGC
TCTTAGTGGCGCAGCTAACGCATTAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACG
GGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGCCTTGACATCCAATG
AACTTTCCAGAGATGGATTGGTGCCTTCGGGAGCATTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGA
TGTTGGGTTAAGTCCCGTAACGAGCGCAACCCTTGTCCTTAGTTACCAGCACGTTATGGTGGGCACTCTAAGGAGACTG
CCGGTGACAAACCGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGGCCTGGGCTACACACGTGCTACA
ATGGTCGGTACAGANGGTTGCCAAGCCCCGANGTGGAGCTAATCCCACAAAACCGATCGTAGTCCGGATCGCAGTCTG
CAC

Endophyte: 34
GAGGGTGCAAGCGTTAATCGGATTACTGGGCGTAAAGCGCGCGTAGGTGGTTCGTTAAGTTGGATGTGAAAGCCCCGG
GCTCAACCTGGGAACTGCATTCAAAACTGTCGAGCTAGAGTATGGTAGAGGGTGGTGGAATTTCCTGTGTAGCGGTGA
AATGCGTAGATATAGGAAGGAACACCAGTGGCGAAGGCGACCACCTGGACTGATACTGACACTGAGGTGCGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCAACTAGCCGTTGGGAGCCTTGAGCTC
TTAGTGGCGCAGCTAACGCATTAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGG
GGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGCCTTGACATCCAATGAA
CTTTCCAGAGATGGATTGGTGCCTTCGGGAGCATTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGNAAAAAA
NTTTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 35
GGTGCAGCGTTAATCGGAATTACTGGGCGTAAAGCGCGCGTAGGTGGTTCGTTAAGTTGGATGTGAAAGCCCCGGGCT
CAACCTGGGAACTGCATTCAAAACTGTCGAGCTAGAGTATGGTAGAGGGTGGTGGAATTTCCTGTGTAGCGGTGAAAT
GCGTAGATATAGGAAGGAACACCAGTGGCGAAGGCGACCACCTGGACTGATACTGACACTGAGGTGCGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCAACTAGCCGTTGGGAGCCTTGAGCTCTTA
GTGGCGCAGCTAACGCATTAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGGC
CCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGCCTTGACATCCAATGAACTT
TCCAGAGATGGATTGGTGCCTTCGGGAGCATTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATGTTG
GGTTAAGTCCCGTAACGAGCGCAACCCTTGTCCTTAGTTACCAGCACGTTATGGTGGGCACTCTAAGGAGACTGCCGGT
GACAAACCGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGGCCTGGGCTACACACGTGCTACAATGGT
CGGTACAGAGGGTTGCCAAGCCGCGAGGTGGAGCTAATCCCACAAAACCGATCGTAGTCCNGATCGCAGTCTGCAACT
CGACTG

Endophyte: 36
GGTGCAGCGTTATCCGGATTTATTGGGTTTAAAGGGTCCGTAGGCGGATCTGTAAGTCAGTGGTGAAATCTCACAGCTT
AACTGTGAAACTGCCATTGATACTGCAGGTCTTGAGTAAGGTAGAAGTAGCTGGAATAAGTAGTGTAGCGGTGAAATG
CATAGATATTACTTAGAACACCAATTGCGAAGGCAGGTTACCTATGTCTTAACTGACGCTGATGGACGAAAGCGTGGG
GAGCGAACAGGATTAGATACCCTGGTAGTCCATGCCGTAAACGATGCTAACTCGTTTTTGGGTTTTCGGATTCAGAGAC
TAAGCGAAAGTGATAAGTTAGCCACCTGGGGAGTACCGTTCGCAAGAATGAAACTCAAAGGAATTGACGGGGGCCCGC
ACAAGCGGTGGATTATGTGGTTTAATTCGATGATACGCGAGGAACCTTACCAAGGCTTAAATGGGAATTGATCGGCTTA
GAAATAGACCTTCCTTCGGGCAANTTTCAAGGTGCTGCATGGTTGTCGTCAGCTCGTGCG***NGAAAAATNTTTGCNCC
CCCNCCNTNTGCCNCGGACCNCNATNNNCCCGNNNNGNTCNNNCCNGNNTNTTCNCNCCCCCNNCNCNNTTNCGCNNT
CNNTATNTAATNNNTCNNTNTNGNCTTTCGTNNTTNNCNCCCGANANCTNCTAACANCNNCNTNCNNCTNNNNTNTTNC
TNNNANTNNNNTTCNCCGNNTTTNNTNNTCCCNNNTNATTCNTTAACNCTAATNCNTNNCCCCTNTC

Endophyte: 37
CTCNGTCGTGAGAGTTGN***GGATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCG
GGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTG
AAATGCGTAGAGATCTGGAGGAATACCNGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAG
CGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGG
CGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACG
GGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAG
AACTTNCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGG***N
AAATGTTTGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 38
NN***TGGTGNCGNGATAGTTGAATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTG
GGCTCAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTG
AAATGCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGC
ACGCAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACG
GGGGCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAG
AACTTTCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCG***NAG
AANTGTTGANNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNTNNNNNNNNNNNNNNNTNNTNNNNNNNNNN

Endophyte: 39
CTNTGGTGNN***GNGANAGTGTGNATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCC
TGGGCTCAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAG
TGAAATGCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAA
GCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTG
GCACGCAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGA
CGGGGGCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCG
AGAACTTTCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCTGA*
**NAAAANGTTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 40
AAGGTGCAAGCGTTCTCGGATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGGCT
CAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAAAT
GCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCACGC
AGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGGG
CCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAGAACTT
TCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGANAAAAATTT
NGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 41
AGGTGCAAGCGTTCTCGGCATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGGCT
CAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAAAT
GCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCACGC
AGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGGG
CCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAGAACTT
TCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGAAANAAGTT
NG*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNN

Endophyte: 42
AAGGTGCAAGCGTTCTCGGATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGGCT
CAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAAAT
GCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCACGC
AGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGGG
CCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGNTCTTGACATGTCGAGAACTT
TCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGANAAAAATTN
TNG*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNN

Endophyte: 43
CGCTCTGTCGTGGCTGTTGANNCATNTCGNGNNGNANN*******AGACCTCGTNCGCGGGTTGTTGCNTCTGCTGTGAAATCC
CGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCG
GTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATAT
ACGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTG
AGAATGTTGNNCCC*******NNNNNNNNNNNNNCNNNNNNNCNCNCNCCNNNNNNNNNANANNNNNTNNNNNCNTNCNNCTN
NCNCNTTNNNCCNNTTNCCCNNNNNCNNNTNTTCNCCTNTNTCNCNNCCCCCCCNTTCNCCCNNCNNTNCCNTTTTTNT
NNNNNCCTNACNTNCCCCNCTCTATTNTNNTCNTNTTNTTCCCNNTNCCANNCCTTTNNCCNNNANNNNAAATNNNTA
NNNNTCCTNATCCCCTAATTTTTTAT

Endophyte: 44
GGN*******GGTGCAAGCGTTAATCGGAATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCC
CGGGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGG
TGAAATGCGTAGAGATCTGGAGGAATACCNGGTGGCGAAGGCNGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGA
AAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTG
AGGCGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTG
ACGGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCA
GAGAACTTNCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGG******
*****NNANNANTTTGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 45
TCNGTCGTGAGGNGTTGCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGC
TCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAA
TGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTG
GGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTT
CCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGG
ACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAA
CGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTG*******NNAAAAA
NNTTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 46
GCTCGGTGCNGNGNNTTGCGNATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGG
CTCAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAA
ATGCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCAC
GCAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGG
GGCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAGAA
CTTTCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGGAAAATG
TTGG***NNNNNGNNNNNNNNNNNNNNNTTNCCCGNGNNNTNNNNNNNNNNNNNNNGNNNNNNNNNNNNNNNCNNN
NNNCNNNTNNNNCNNTCNNNNNNNNNNNGNCNNNNNCNNNNNNNTNNNNNGNTTNGNNNNNNNNNNNCNNNNNNNNN
NNNNNNNNNNCCNNNNNNNNNGGNGNNNNNNGNNNNNNANNGNGGNNNNNGNNNNNNCNNNNTANNNANNCNCGN
GNNNNNCCNCCNTNNNNTN

Endophyte: 47
CGCTCNGTCGTGAGGNGTTGANNCATTATNGGGNGTANNGAGCTCGTAGGCGGNTTGTCGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTANATACCCTGGTAGNCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCA
CGGTTTCCGTGACGCANCTAACGCATTAAGTTCCCCGCCTGGGGAGTACTGCCGCAAGGCTAAAACTCAAAGGAATTG
ACNGGGGACCCNCACAANACGGGTGGAGCATGCCGAATTAATTTGATGCANCCCNAANAACCTTACCAANGCTTGACA
TATTCCNAAAACGNGGCCCAAAAATNGTNCAACTNTTCTGGANCCCTCGTAAAACNNNGGTGGGTGCAANGGCTNTTT
CNCACCTCNTGTCTTNAAGAANTTTNANCCNNCTCNTNTCCTATNANTCANNTNTTNNNNNANTANTNNTATTCANCNN
TNCATNCNNATGTAACCGATNNCNCNCTTTTCCTTNNTNTCTTCTNCCTANTNTCCCTCTATNTNCNNNNCTNNTCCCCC
CNATNTAGNCNTTCNCTNTANTTCCNNNNGATTNTNTTNNNAATTTNANTNNCNAANNCCCCCCCCTNTANCCNNNCNA
TNTTTTNTCTNCCNCNCNNAANNCCCTTTNTTCCNNT

Endophyte: 48
GTCTACAAGGTAGCCGTAAGCTTGGCNCCCGGGTAAAGCGCGCGTAGGTGGTTCGTTAAGTTGGATGTGAAAGCCCCG
GGCTCAACCTGGGAACTGCATTCAAAACTGTCGAGCTAGAGTATGGTAGAGGGTGGTGGAATTTCCTGTGTAGCGGTG
AAATGCGTAGATATAGGAAGGAACACCAGTGGCGAAGGCGACCACCTGGACTGATACTGACACTGAGGTGCGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCAACTAGCCGTTGGGAGCCTTGAGCT
CTTAGTGGCGCAGCTAACGCATTAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGG
GGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGCCTTGACATCCAATGA
ACTTTCCAGAGATGGATTGGTGCCTTCGGGAGCATTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGAT
GTTGGGTTAAGTCCCGTAACGAGCGCAACCCTTGTCCTTAGTTACCAGCACGTTATGGTGGGCACTCTAAGGAGACTGC
CGGTGACAAACCGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGGCCTGGGCTACACACGTGCTACAA
TGGTCGGTACAGAGGGTTGCCAAGCCGCGAGGTGGAGCTAATCCCACAAAACCGATCGTAGTCCCGATCGCAGTCTGC
AACTCGACTGCGTGAAG

Endophyte: 49
AAGGTGCAAGCGTTCTCGGATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGGCT
CAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAAAT
GCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCACGC
AGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGGG
CCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAGAACTT
TCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGGAAAAAAATT
TTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNNNNNNNCNCGNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 50
GCTCGTTTGTGAGAGTTGANNATTACTNTGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGG
CTCAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAA
ATGCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAANCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCAC
GCAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGG
GGCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAGAA
CTTTCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTG***NNA
ATGTTGNCNCCCNTCCNCNGCNCACCCTTNNNCNNNNCNTCCNATNTCTTNNNNTNNNGNNNCTCNCGTTTCCCCNNTN
CCCNTTTTTCNCGCGTCGNCTANNGTTCGANCTNNNCNCCNNCGNNCCNNNNNTNTCCNNNNNGNCCNCNATATCCNG
NNANNCNNTCNNCCCNNNNNATNTNNNTTNCCAGCTTCNTGNNGTCTTNNNNACGCCCTNNANTTTNTTCTCNCCCNCN
CNCCCCCATCNCTNNAATN

Endophyte: 51
GGGTGCAAGCGTTACTCGGAATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGGC
TCAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAAA
TGCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCACG
CAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGG
GCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAGAACT
TTCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGAAAAAANTT
TGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNCNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNN
NNNNNNNCNNNNNNNNNNNNNNNNANNNNNNNNNNTNNNNNNNNNNCNNNNNNNNNCNNNNCNNNNNNNCNNCN
NNNNNNNNNNNNNNNNNNCNCNNNNNNNNNNNNNNANNNNNNNNNNNNNANNNNNNCNGANNNNNNNNCNNNCNN
N

Endophyte: 52
GGTGCAGCGTTAATCGGAATTACTGGGCGTAAAGCGCGCGTAGGTGGTTCGTTAAGTTGGATGTGAAAGCCCCGGGCT
CAACCTGGGAACTGCATTCAAAACTGTCGAGCTAGAGTATGGTAGAGGGTGGTGGAATTTCCTGTGTAGCGGTGAAAT
GCGTAGATATAGGAAGGAACACCAGTGGCGAAGGCGACCACCTGGACTGATACTGACACTGAGGTGCGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCAACTAGCCGTTGGGAGCCTTGAGCTCTTA
GTGGCGCAGCTAACGCATTAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGGC
CCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGCCTTGACATCCAATGAACTT
TCCAGAGATGGATTGGTGCCTTCGGGAGCATTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATGTTG
GGTTAAGTCCCGTAACGAGCGCAACCCTTGTCCTTAGTTACCAGCACGTTATGGTGGGCACTCTAAGGAGACTGCCGGT
GACAAACCGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGGCCTGGGCTACACACGTGCTACAATGGT
CGGTACAGAGGGTTGCCAAGCCGCGANGTGGAGCTAATCCCACAAAACCGATCGTAGTCCGGATCGCAGTCTGCAACT
CGACTGCGTGAAGTCGGAAT

Endophyte: 53
GAGGGTGCAAGCGTTAATCGGATTACTGGGCGTAAAGCGCGCGTAGGTGGTTCGTTAAGTTGGATGTGAAAGCCCCGG
GCTCAACCTGGGAACTGCATTCAAAACTGTCGAGCTAGAGTATGGTAGAGGGTGGTGGAATTTCCTGTGTAGCGGTGA
AATGCGTAGATATAGGAAGGAACACCAGTGGCGAAGGCGACCACCTGGACTGATACTGACACTGAGGTGCGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCAACTAGCCGTTGGGAGCCTTGAGCTC
TTAGTGGCGCAGCTAACGCATTAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGG
GGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGCCTTGACATCCAATGAA
CTTTTCCAGAGATGGATTGGTGCCTTCGGGAGCATTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGAAAAA**
**NNNNTTNGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNAGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNNN
NNNTNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 54
CTANGTGTGCANGNGGNNNATGCGGTAATTACTGGGCGTAAAGCGCGCGTAGGTGGTTNGTTAAGTNNGATGTGAAAG
CCCNGGGCTCAACCTGGGAACTGCATTCAATACTGTCCAGCTAGAGTATGGTAGAGGGTGGTGGAATTTCCTGTGTAGC
GGTGAAATGCGTAGATATAGGAAGGAACACCNNTGGCGAAGGCNACCACCTGGACTGATACTGACACTGAGGNGCGA
AAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGNCAACTNGCCGTTGGGAGCCTTG
AGCTNTTAATGGNCCAACTTACCCNTTAANTTNACCGNCTNGGGANTACCGGCNCNAGGATNAAACTNAAATGAATTG
NCCGGGGCCCNCACNANCNGGGGANCATNNGGNTTAATTNCAANCNACCCCAAAAACCTTACCNNGNCTTGACNTTCA
ATGAACNTTNCAAAAANNGATTGGNGCCTTNNGGAACNTTGAAACNNGNGCTNNATNGNTNNCNTCAACTTNTGTCGA
AAAANATNTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 55
AAGGTGCAAGCGTTACTCGGATTACTGGGCGTAAAGCGTGCGTAGGTG
GTGGTTTAAGTCTGTTGTGAAAGCCCTGGGCTCAACCTGGGAATTGCA
GTGGATACTGGATCACTAGAGTGTGGTAGAGGGTGGCGGAATTCCCG
GTGGATACTGGATCACTAGAGTGTGGTAGAGGGTGGCGGAATTCCCGGTGGATACTGGATCACTAGAGTGTGGTAGAG
GGTGGCGGAATTCCCGGTGTAGCAGTGAAATGCGTAGAGATCGGGAGGAACATCCGTGGCGAAGGCGGCCACCTGGG
CCAACACTGACACTGAGGCACGAAAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATG
CGAACTGGATGTTGGGTTCAACTTGGAACCCAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGC
AAGACTGAAACTCAAAGGAATTGACGGGGGCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGA
ACCTTACCTGGTCTTGACATCCACGGAACTTTCCAGAGATGGATTGGTGCCTTCGGGAACCGTGAGACAGGTGCTGCAT
GGCTGTCGTCAGCTCGTG***NNAAAAAANNNTTTNGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 56
GCTCNGTCGTGANANGTTGANNCATTTCCGGGCGNANNGANCTCGTNCGCGGANTGTNGCGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCTTGCANTGGGTACGGGCAGACTAGAGTGCGGTAGGGGANATTGGAATTCCTGGTGTANCCGG
TGGAATGCCGCATATATCAGGAGGAACACCTGATGGCGGAAGGCAGATCTCTGGGCCGTAACNTGANGCTGANGANCN
GAAATCNTGGGGAGCGAANANGATTATATNCNCNTGGTTNTCCANGCCGTNAACNGCNGGGNGCTANATGTANGGAC
CCTTNCCNTNGATTCTGTNTCNGTANCTNACGTATTACATTCCTCCCTTCCTNGGNANTACCNGNNNNNATNTTTNATAN
NCTNNNNNGANTTGNCGGTNGNCTCNCNCNACCAGCNNTNCTATGCTGNNTNNCTNTNNCTNNTATCCCATAATNANC
NNNACNATTGNTTGACTTTACANATNNAANCNNGCCANAGNANGGATCANTNTNTNTATGTTNNTNNTNTCTATNNNC
TGCGNCGCNCNGNNCNAACAGNNCNACANNCNNGNTNNACNCTNNAGCNNCNTNNNCNCNNGGCNNCCNTCNCTCAC
NTNNNNANNNNCTCANACGNTNATNANNTANTTNNTNANNNANNAATTTTCNNTNNCNCATTTTACNNNTTTCTTTCNC
GTTGCNANNCGNNNNGATTATNANTAATNNNNNTNTNTTACCTTATCNCCCNCTNNGNNGCNNGNNNAGACNNACTNN
NNNNNGTTCCNNCNCGNTTTANNNATTNATNANAAANNATATTACNANGNTCGAATNANNCNNAATNTNATTAACCNC
NNCCATANNCNCCNCNNNTTTTTTTT

Endophyte: 57
AAGGTGCAAGCGTTCTCGGATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGGCT
CAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAAAT
GCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCACGC
AGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGGG
CCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAGAACTT
TCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGAAAAANNTTT
GG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 58
GTGCNAACAAGGTAGCCGTAANCTTGGGTCCCGGNGNGCACGTAGGCGGATATTTAAGTCAGGGGTGAAATCCCGCAG
CTCAACTGCGGAACTGCCTTTGATACTGGGTATCTTGAGTATGGAAGAGGTAAGTGGAATTCCGAGTGTAGAGGTGAA
ATTCGTAGATATTCGGAGGAACACCAGTGGCGAAGGCNGGCTTACTGGTCCATTACTGACGCTGAGGTGCGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGTTAGCCGTCGGGCAGTATACTGTTC
GGTGGCGCAGCTAACGCATTAAACATTCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGGGG
CCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCTCTTGACATTCGGGGTATG
GGCATTGGAGACGATGTCCTTCAGTTAGGCTGGCCCCAGAACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGA
TGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTCGCCCTTAGTTGCCAGCATTTAGTTGGGCACTCTAAAGGGGACTGC
CGGTGATAAGCCGAGAGGAAGGTGGGGATGACGTCAAGTCCTCATGGCCCTTACGGGCTGGGCTACACACGTGCTACA
ATGGTGGTGACAGTGGGCAGCGAGACAGCGATGTCGAGCTAATCTCCAAAAGCCATCTCAGTTCGGATTGCACTCTGC
AACTCGAGTGCATGAAGTTGGA

Endophyte: 59
AGGTGCAAGCGTTCTCGGATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGGCTC
AACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAAATG
CGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGCGTGGG
GAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCACGCA
GTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGGGC
CCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAGAACTTT
CCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTG***NGNNGAAANNN
TTTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 60
GGAGGGTGCAAGCGTTAATCGGAATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTTAAGTCAGATGTGAAATCCCC
GGGCTTAACCTGGGAACTGCATTTGAAACTGGCAGGCTTGAGTCTCGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGT
GAAATGCGTAGAGATCTGGAGGAATACCNGGTGGCGAAGGCNGGCCCCCTGGACGAAGACTGACGCTCAGGTGCGAA
AGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTTCCCTTGA
GGAGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGA
CGGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAG
AGAACTTAGCAGAGATGCTTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTGTGTGNAAAA
AA***NNNTTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 61
CGNTCTGTCGTGAAANGTTGACNCATCTCCGNNGNANNAGACCTCNTNCGCGGNATGTTGCNTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGTCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTTACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCAC
GGATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
NAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCNTGA
NATGTTGGTNTTTT***NNNTCGACNCTNNCANCNTTNNCNCTCNGCCCCCTTNNGNNATANNANTCNNCTCNNNNCNT
ACCCCCCNNTNTNNCGATTTCCCCCCCCCCNCNNTNCCTCNNCTCACNNTTTCCCANCTANNCCCTNTTTCNCCCCCNTNN
CCCGNTTNNNCCNTGNAATTNNTNNCNCCCNNTATANTAGTNNNATTNATNTTGTCGTGGNTCCCTNTCTCACNNCNNC
NNCNTNTTNCNTTCACCCNNNCNNTCNCCNATTAANTNTANT

Endophyte: 62
CGCTCNGTCGTGAGANGTTGNGTCATTATTGGGCGTAAAGGAGCTCGTNTGCGGATNGTNGNGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCGATGGCNGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTANTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAANTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCTGGATTAATTCNATGCAACGCGAAGAACCTTACCAAGGCTTGACATA
TACNAGAACGGGCCAGAAATGGTCAACTCNTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCG
TGAGAATNGCNGGNCCAAT***CCCCCCCTCCNNNTTTNTCNTTANTATANTTNNCNCNNNNCNNNNTANNCGNNTNAT
NNATNCCCCNNNNCNCTNNCCTTTCNNCNTTTNNNGNAGANACCCCCTAAANNCCNCCTTTNATTNCANCNNNAATTN
CTCCNNNANNATANTNNNTTNANCATNTTNNNNNCTGCNCNACNANTCCNNNCNCTNTTNACTCNCCCNCANNATNCC
NNCTATTNTTATT

Endophyte: 63
GGAGGTGCAGCGTTAATCGGATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGG
CTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAA
ATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCNGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGGCG
TGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGG
GGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAGAA
CTTNCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAAATG
TTGGGTTAAGTCCCGCAACGAGCGCAACCCTTATCCTTTGTTGCCAGCGGTNCGGCCGGGAACTCAAAGGAGACTGCC
AGTGATAAACTGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGAGTAGGGCTACACACGTGCTACAAT
GGCGCATACAAAGAGAAGCGACCTCGCGAGAGCAAGCGGACCTCATAAAGTGCGTCGTAGTCCGGATTGGAGTCTGCA
ACTCGACTCAT

Endophyte: 64
AGTACTNACANGTNGCCCGNAAGCTNTTGTTCTCNCGGAAANGGCAACATNGGCGGN***CTTTTAAGTCGGAGGTGAA
AGCCCAGGGCTCAACCCTGGAATTGCCTTCGATACTGGGAGTCTTGAGTTCGGAAGAGGTTGGTGGAACTGCGAGTGT
AGAGGTGAAATTCGTAGATATTCGCAAGAACACCGGTGGCGAAGGCNGGCCAACTGGTCCGAAACTGACGCTGAGGC
GCGAAAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGCCAGCCGTTGGGGA
GCTTGCTCTTCAGTGGCGCAGCTAACGCTTTAAGCATTCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAA
TTGACGGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCNAAGCAACGCGCAGAACCTTACCAGCTTTTGACAT
GTCCGGTTTGATCGGCAGAGATGCCTTTCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGTCAGCTCG
TGTCCGNGAGATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTCGCCCCCTAGTTGCCATCATTCAGTTTGGGAACTC
TTAGGGGGACTGCCGGTGATAACCCGCCNAGAAGGTGGGGGATGACGTCAAGTCCCTNATGGCCCTTACAGGCTGG***
NGCTNCACACNTGCTACAATGGCGGNGACAATGGGCANNNNNAGGGNGANCTCNANCCTAATTCCAANAGCCCCCTC
ANTTNNAAATTGCACTTCCNNCTNCNNTGCATT

Endophyte: 65
GCTCNGTCGTGAGGAGTTGCGGTATTATTGGGCGTAAAGGAGCTCGTANGCGGTTTGTCGCGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGTCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTTACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCA
CGGATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTG
ACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATA
CGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGA
AAATGTTTG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NN

Endophyte: 66
TGGCTCTGTCGNGAAN***GTTGACNTTTTGGGCGTAAANAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGTCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTTACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGGTTGGGAACTAGTTGTGGGGTCCATTCCA
CGGATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTG
ACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCTGAAGAACCTTACCAAGGCTTGACATAT
ACGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGNCAGCTCGTGTCGT*
**NAAATGTTGANCACTNNTTNTNNANTCNGCNCNNCCTTTCNGCNCCNGTNCNNANATCATTNTANTTATNANNTNTG
NNCCTACNACCNCCTTTCTGTNGTTCNTCTTNCNTNNCCCTATTTCCCTNATGCTNATNCNNCCCNTNCCNNGATATTAN
NANCNTTNATTTCTNTTNNTTNNTCTTTATNTNNATCNCCNCAATNTANATAACCCCNNCANNNANTTNNCCCGCATNN
NNCANCNTNATNNCNNN

Endophyte: 67
CNNGGTGCNGNGNNN***TGCGGATTACTGGGCGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTG
GGCTCAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTG
AAATGCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGC
ACGCAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACG
GGGGCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAG
AACTTTCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGGAAAA
AAGGTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 68
GGAGGTGCAAGCGTTAATCGGATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGA
AATGCGTAGAGATCTGGAGGAATACCNGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGGC
GTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGG
GGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAGA
ACTTNCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAAAT
GTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTATCCTTTGTTGCCAGCGGTNCGGCCGGGAACTCAAAGGAGACTGC
CAGTGATAAACTGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGAGTAGGGCTACACACGTGCTACAA
TGGCGCATACAAAGAGAAGCGACCTCGCGAGAGCAAGCGGACCTCATAAAGTGCGTCGTAGTCCNGATTGGAGTCTGC
ACTC***N

Endophyte: 69
GGNGCTGNNGGNNGNTCGNN***ATTACTGGGCGTAAAGGGAGCGTAGGCGGACATTTAAGTCAGGGGTGAAATCCCG
GGGCTCAACCTCGGAATTGCCTTTGATACTGGGTGTCTTGAGTATGAGAGAGGTGTGTGGAACTCCGAGTGTAGAGGTG
AAATTCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCGACACACTGGCTCATTACTGACGCTGAGGCTCGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATTGCTAGTTGTCGGGATGCATGCATTTC
GGTGACGCAGCTAACGCATTAAGCAATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGGGG
CCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCACCTTTTGACATGCCTGGACCGC
CAGAGAGATCTGGCTTTCCCTTCGGGGACTAGGACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATGTTG
GGTTAAGTCCCGCAACGAGCGCAACCCTCGCCATTAGTTGCCATCATTTAGTTGGGAACTCTAATGGGACTGCCGGTGC
TAAGCCGGAGGAAGGTGGGGATGACGTCAAGTCCTCATGGCCCTTACAGGGTGGGCTACACACGTGCTACAATGGCGA
CTACAGAGGGTTAATCCTTAAAAGTCGTCTCAGTTCGGATTGTCCTCTGCAACTCGAGGGCATGAAGTTGGAATCGCTA
GTAATCGCGG

Endophyte: 70
CGCTCNGTCGTGAGNGTTGANTNTTTTGGGCGTAAAGGAGCTCGTANGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGG
TTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGG
ATGTTTGA***NNCNNNTNCCGTNANNCCCAATNNTTCNANATCNNCNNNCANNNCANATTTTNTCNNCCCNCANTCCC
CCTTTCNNCATTTTTNNTNNNTNNNCTTNNNNTCTCCANANNNCNCCTANCCNGCAAATCNCCNCTTNNNNCNTCNTTN
GCNANTANNNTNATNCCNNCNNTNCANTNCNTTTCCATCNNNNCNNNCCCTNCTNCTNCCCNCCCNTNTTTTNNCNNCC
NNCGTTCCCCNTCNTTTTNNTC

Endophyte: 71
GTNTACNCGAGTNNNNCCCNATGNNCGTNNTNTNGCGGAAATACTNNTNGGCGGCTTGTCGCTGTCTGCTGNGAAATC
CCGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGC
GGTGGAATGCTGCAGATATCAGGAGGAACACCAGATGGCAGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAG
CGAAAGGGTGGGGAGCAGNNNGGCTTANATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCA
TTCCACNGTTTCCNTGACGCANCCTCACGCATTAATTTTCCCCGCCTGGGGANTNCNGTCNTAANGCTAATACTCANAG
GAATTGACNGGGACCCNCACAACCGGCGGAGCCATGCGNATCAATTTGAATGCANCGCNNANCAACCTTACCAAGGCC
TTGNCATNTNCNACACCNGNCCACAAANGGTCAACTCTTTNNACACTTCTANANACAGGNGNNTGCNTNNNCTNANNN
TAGCCNCCCTNATTNTGAAAANGTTACNCNNNAANNCCNCCCATCNCAGCNCAAANCCTCCTANCATAATNTTANC***
NNCNNGTNTNGNTNNTAANCTTNNNGNCACTNCTNNCNNNGNCCACTCCTNCNGANCGTNNAGTTTGANCNNCAAATA
CNNCATGCNNCTTNNTTGTCCNANTNCCNNACCCCCTNGNNTNAAATACCCCCNNTCTANAATGACNTGNNNNNCTNT
NTAGNNTGANCNNCATACNNAAATAGNCNTTANNCANCNTCNGNTTAAGGTTTTNACNCNCACTCTCNCCACTT

Endophyte: 72
ANCGACNNGNNNNCGTAAGGTTNGGTTCCGGGAAANCGTNCNCANGCGGTGATGTAAGACAGTTGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATNTGTGACTGCNTTGCTGGAGTACNGCACAGGGGGATGGAATTCCGCGTGTANCAGTGA
AATGCGTAGATATGCTGGAGGAACACCGATGGCGGAAGGCNATCCCCTGGGCCTGTACTGACGCTCATGCACNAAAGC
GTGGGGAGCAAANGGGATTAGATACCCTGGTANTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGNCT
CAGTTNCGAAGCTAACNCNTGAAGNTGACCCCCTNNGGAGTACGGNCGCAAGGGTGAAACTCNAANGAATTGACGGG
GACCCCCACAAGCGGNGGATGATGTGGTTTAATTNTCATNCAACGCCGAAAAACCTTNCCCACCTNTGNCATNCNCGN
NNTNTTNCCNGNCNATGGCTTANTGCTTCGAAAGACANCCNGGACNCCACGNCNNTNCATGGCCTGCCNTGAAGGTCN
CCNTACGNGAGATTGTTGGGTTAANTCCNGNACNGACNGCAACCCTNGTCTATTATNTCCTTACA***NNNAGCTNNCG
GCGACTCNNNTTCNCAACNGNNNCGAACNNACGCNGNTCGAAGGGGCGGCNGNNCNGACAGGNCCTCNTCGGGCCNN
NNNAAGTTGGGGGNTNNNNCCNNACANNCNNTNNGCCTNGTNCNATACGGNNNCNCAACCCNNGNNGGTGNNACCNN
CTNNANTNTNNNGCNGGNCNTNANNCNCAANCANTNGNTNCCNGCNNT

Endophyte: 73
CGCTCNGTCGTGAGNGTTGNNN***ATTATTGGGCGTAAAGGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCTG
GTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATAT
ACGAGAACGGGCCANAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCCTGTC***
NTGNAANGTTGCCCNACCTNCNNCNCCCCNCTCNTNTGTTNNNCTNNTCACCACCNTNNANCNNNTCNCTTNTNCANTN
NCANNNTCNTTTNATNNNTCACNNNATNCTCCTNCNTCTNCNTTCCCCTCCNCCTCCNNNNCCNCCACTCCCCCCCNNC
NNTNCCNCNTTCTCNNNCCCCTANNACCTCCCNCCTNCTANTCCNNNTATNNACNNNATANNNNTTCNNCNCCNTCCCC
NNNCCNCNCNATNTNNTNTTNTT

Endophyte: 74
GTCNACAAGGTAGCCGTAAGCTTGGTTCCCGGGTAAAGAGNTCGCAGGCGGTTANTTAAGACATGATCGTGAAATCCC
GAGGCTCAACCTCGGNNCTGCATTGGGTACTGGNTCGACTAGAGTGCCGGCAGNGGAGAATGGAATTCCTGGTGTAGC
AGGTGAAATGCGNAGATATCCGGAGGAACACCCGATGGCGAAGGCAATNCNCTGGGCCTTTACTGACGCTGATGCGCG
AAAGGGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACCCCNTAAACGATGNGAACTAGTTGTGGGGNCNNTA
CTANNNNATNNGTGACGCTNACTACCNCANTNNGACCCCCTCCTGNGGANTACNGCCGCNNGGANANTACNNAAANG
AANCGACGGNNNCCCCNACNAGCGGANGATCNTGCTGANTNATATGNNGCAACNNNAANANNNNNNCCNTNGCNCGT
CTTNTACANNATCNGGNCATAAATGGTNAANTCTNNGNANACNCGNACACAGGTGGTGCATGGNTGTCGTCAGCTCGT
GTCGTGAGATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTNGTNNTATGTTGCNANCACNTAANGGTGNNANCTCA
NGGGATACTGCCGGGGTCAACNNGGAGGAAGGTGGGGATGACGCNNANTCATCNTGCNCCTTATGTTNNGNGCTTCAN
NCATGCTANANTGGCCGGNACNAANGGCTGCNATACCGGGANGTGNANCGAATCCCAAANAGCCGGCCCCATCTCNG
ATTGANGNNTGCNCTCGA

Endophyte: 75
TCNACACGGTAGCCGTAAGCTTNGTTNCCGGGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCANTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGANGAGCGAAAGGGT
GGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGT
TTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGG
GGACCCGCACAAGCGGCGGAGCATGCNGATTAATTCGATGCAACGCGAANAACCTTACCAAGGCTTNNCATATACCAT
AACGGGCCAGAAATGNTCANCNTCTNTGGACACNCTNTAAACAGGTGGTGCATGGNTGTCNTCAACNTCGTGTCGTGA
AGATGTTGGGGTTTAAGTNTCCGCAACGAANCGCAAACCCTTTGTNTNTATGTTTGCCACCCCCCTAATGGGTGGGAAC
TNCATGNNGATACTNACGGGGGTCNCCNTCNGA***NNNGAAGGTNNNNAATNACCCCTNNATCNTCATNCCCCCTTAA
TCTCTANNGCTNTCACTCATANCTNNAAATGGCACGCTNNANAAGGCNNCANCCCNNCGATGNNNGANNNAATCCCNA
ACANCACGNNCCNCNTCCNNAT

Endophyte: 76
CNCAAGCGTTATCCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCTCAA
CCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAATGCG
CAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGGTGGGGA
GCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTCCGT
GACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGACCC
GCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAACGGG
CCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGATGTTGGGT
TAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACTGCCGGGGTC
AACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACAATGGCCGGT
ACAAAGGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGAGGTCTGCACTCGACC
TCATGA

Endophyte: 77
TAGGCGCAGCGTTTCCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCTC
AACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAATG
CGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTGGG
GAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTCC
GTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGAC
CCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAACG
GGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGATGTTGG
GTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACTGCCGGGG
TCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACAATGGCCG
GTACAAAGGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTG

Endophyte: 78
CTCNGTCTGAGNGTTGCGGATTTTGGGCGTAAAGGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCT
CAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAAT
GCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGGTGG
GGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTC
CGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAAC
GGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGAAAAAANG
TTGG***NNNNNNNNNNNNNCNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
CNNNNNNNNNNNNNNNNNNNNNNNCCNNNNNNNNNNNNNNNCCNCNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNCCCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNCNNNNCNNNNCCNNNNNNNNNN

Endophyte: 79
CCTCNGTCN***TGAGTGTTGCGGCATTATTGGGCGTAAAGAGCTCGTGTGCGGANANNTNGGTCTGCTGTGAAAACTG
GAGGCTCAACCTCCAGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGGCCATTCCA
CGGTCTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTG
ACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATA
CGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTNG
AATGTTGGTTC***NTNTNTNNCCNCCCNNCNNTTNCCNNCCCTCCCCNCNTTCNCTCTNTNNNCNNCNCNNNNNAATTN
NNCNTTCCCCNNNTTNNNNNTCATNCNNNNNNTNTNNNTANTTNNNTNTCCCNNNGTTNCNCCNTTNNCCCCTCNNTNN
NNNCAATNTCNNNCNCNTNCTCTCTCNNCNNCTNNNANNTNNNCCCACNNTNANTTTNNNTNNNNTTTNTGTCNNTTNC
NNACCTNANNCCTCTC

Endophyte: 80
CGCTCNGTCGTGAGNTGTTGCN***TATTATTGGGCGTAAAGAGCTCGTANGCGGNTNGTCGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGTCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTTACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCA
CGGATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTG
ACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATA
CGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTNA
GAATGTTGG***NNNNNNNNNNNNNNNTNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNTNNNTNNNNNNTNNNNNNNNNNNNNNCCNNNNNNNNNNNNNN
NNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNNTNNNNTNNNNNNNNNNNNNNNNNTNCNNNNACNNNNCNCNNN
CCNNTNNNNNNT

Endophyte: 81
CTCGGTCCNGAGATGTTGCGGATTATTGGGCGTAAAGGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGG
TTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGNAA
ATGTTG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNN

Endophyte: 84
AAGGGGCTGCNTNGNTCGGATCACTGGGCGTAAAGGGCGCGTAGGCGGACTTTTAAGTCGGAGGTGAAAGCCCAGGG
CTCAACCCTGGAATTGCCTTCGATACTGGGAGTCTTGAGTTCGGAAGAGGTTGGTGGAACTGCGAGTGTAGAGGTGAA
ATTCGTAGATATTCGCAAGAACACCGGTGGCGAAGGCNGGCCAACTGGTCCGAAACTGACGCTGAGGCGCGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGCCAGCCGTTGGGGAGCTTGCTCTTC
AGTGGCGCAGCTAACGCTTTAAGCATTCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGGGG
CCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCTTTTGACATGTCCGGTTTGA
TCGGCAGAGATGCCTTTCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGGAAAAT
***NTNTTNGNNNCCNCNNNNNNCNCTTNNNCNNTGTTNNCNGNGNNNGNCNGNNCNGGANANGNGCTTNNNCATNTN
ANNNNNTNTTNTTNNGCNNAANCCNCNNNNTNNNNAANNCANAACNNNNNNTNTCTCNNACTACNGNNTNNCNCCNN
TCNNNCCCTAGNNTCNNCNCNNNNTNNNNNCNNCNACNNANNNGNNTNCNNNNNCCATNNAAANNNNNCCCCNNTCT
NTNNNCCNNTNTNCCTCCTACCNNNANCCCNCANN

Endophyte: 85
TAGGGTGCAGCGTTAATCGGATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGTTGTGAAATCCCCGGG
CTCAACCTGGGAACTGCATCTGTGACTGCATTGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGAA
ATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCAG
TAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGAC
CCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATTTG
CCAGAGATGGCTTAGTGCTCGAAAGAGAGCCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATGTT
GGGTTAAGTCCCGCAACGAGCGCAACCCTTGTCATTAGTTGCTACATTCAGTTGGGCACTCTAATGAGACTGCCGGTGA
CAAACCGGAGGAAGGTGGGGATGACGTCAAGTCCTCATGGCCCTTATAGGTGGGGCTACACACGTCATACAATGGCTG
GTACAAAGGGTTGCCAACCCGCGAGGGGGAGCTAATCCCATAAAACCAGTCGTAGTCCGGATCGCAGTCTGCAACTC**
*N

Endophyte: 86
TAGGGTGCAAGCGTTAATCGGATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGTTGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATCTGTGACTGCATTGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGA
AATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCA
GTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATTT
GCCAGAGATGGCTTAGTGCTCGAAAGAGAGCCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATG
TTGGGTTAAGTCCCGCAACGAGCGCAACCCTTGTCATTAGTTGCTACATTCAGTTGGGCACTCTAATGAGACTGCCGGT
GACAAACCGGAGGAAGGTGGGGATGACGTCAAGTCCTCATGGCCCTTATAGGTGGGGCTACACACGTCATACAATGGC
TGGTACAAAGGGGTTGCCAACCCNCNANGGGGAGCTAATCCCATAAAACCANTCGTANTCCGGATCG

Endophyte: 87
GTGGCAGCGTTATCCGGAATTATTGGGCGTAAAGCGCGCGTAGGCGGTTTTTTAAGTCTGATGTGAAAGCCCACGGCTC
AACCGTGGAGGGTCATTGGAAACTGGAAAACTTGAGTGCAGAAGAGGAAAGTGGAATTCCATGTGTAGCGGTGAAAT
GCGCAGAGATATGGAGGAACACCAGTGGCGAAGGCGACTTTCTGGTCTGTAACTGACGCTGATGTGCGAAAGCGTGGG
GATCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAGTGCTAAGTGTTAGGGGGTTTCCGCCCCTTAG
TGCTGCAGCTAACGCATTAAGCACTCCGCCTGGGGAGTACGACCGCAAGGTTGAAACTCAAAGGAATTGACGGGGACC
CGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAAATCTTGACATCCTCTGACCCCTC
TAGAGATAGAGTTTTCCCCTTCGGGGGACAGAGTGACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTGGGAAANNGNT
TGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 88
CTCGGTNTGAGNGTTGCGGATTATTGGGCGTAAAGCGCGCGTAGGCGGTTTTTTAAGTCTGATGTGAAAGCCCACGGCT
CAACCGTGGAGGGTCATTGGAAACTGGAAAACTTGAGTGCAGAAGAGGAAAGTGGAATTCCATGTGTAGCGGTGAAAT
GCGCAGAGATATGGAGGAACACCAGTGGCGAAGGCGACTTTCTGGTCTGTAACTGACGCTGATGTGCGAAAGCGTGGG
GATCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAGTGCTAAGTGTTAGGGGGTTTCCGCCCCTTAG
TGCTGCAGCTAACGCATTAAGCACTCCGCCTGGGGAGTACGACCGCAAGGTTGAAACTCAAAGGAATTGACGGGGACC
CGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAAATCTTGACATCCTCTGACCCCTC
TAGAGATAGAGTTTTCCCCTTCGGGGGACAGAGTGACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTGGAAAAAAANT
TG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNN

Endophyte: 89
CCTCNGTCGTGAGNGTTGCGNATTATTGGGCGTAAAGGAGCTCGTANGCGGATNGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACG
GATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACG
AGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGT***N
NNATGTTGNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNCNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNCNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNNCNNCNNACTNNNC
NANNNNNNN

Endophyte: 90
AAGGGGCTGCNTNGCTCGGATTACTGGGCGTAAAGGGAGCGTAGGCGGACATTTAAGTCAGGGGTGAAATCCCGGGGC
TCAACCTCGGAATTGCCTTTGATACTGGGTGTCTTGAGTATGAGAGAGGTGTGTGGAACTCCGAGTGTAGAGGTGAAAT
TCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCGACACACTGGCTCATTACTGACGCTGAGGCTCGAAAGCGTGGG
GAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATTGCTAGTTGTCGGGATGCATGCATTTCGGTG
ACGCAGCTAACGCATTAAGCAATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGGGGCCCG
CACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCACCTTTTGACATGCCTGGACCGCCAC
GGAGACGTGGCTTTCCCTTCGGGGACTANGACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGNGANGAAAAA***NNT
NNGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 91
AAGGGGCTGCGTTGCTCGGATTACTGGGCGTAAAGGGAGCGTAGGCGGACATTTAAGTCAGGGGTGAAATCCCGGGGC
TCAACCTCGGAATTGCCTTTGATACTGGGTGTCTTGAGTATGAGAGAGGTGTGTGGAACTCCGAGTGTAGAGGTGAAAT
TCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCGACACACTGGCTCATTACTGACGCTGAGGCTCGAAAGCGTGGG
GAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATTGCTAGTTGTCGGGATGCATGCATTTCGGTG
ACGCAGCTAACGCATTAAGCAATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGGGGCCCG
CACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCACCTTTTGACATGCCTGGACCGCCAC
GGAGACGTGGCTTTCCCTTCGGGGACTAGGACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGNGAAAAGTNTTGG*
**NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 92
CAAAGNTGCTNTCGTNNTACNTN***TTACTGGGCGTAAAGCGCACGTAGGCGGACATTTAAGTCAGGGGTGAAATCCC
GGGGCTCAACCTCGGAACTGCCTTTGATACTGGGTGTCTTGAGTGTGGAAGAGGTCAGTGGAATTGCGAGTGTAGAGG
TGAAATTCGTAGATATTCGCAGGAACACCAGTGGCGAAGGCNGGCTGACTGGTCCACAACTGACGCTGAGGTGCGAAA
GCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGTTAGCCGTCGGCAAGTTTACT
TGTCGGTGGCGCAGCTAACGCATTAAACATTCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACG
GGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCCCTTGACATCCTACG
ATCGCTACAGAGATGTAGTTTCCACTTCGGTGGCGTAGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGGAGAA
AA***NNNTTGGNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNAGNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 93
GCTCNGTCTGAGNGTTGANTCTTTNGGGCGTANN***GGAGCTCGTACGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGG
TTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGNTCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTNANA
TGTTG***NNNNNNACCNCCCCCCTNNTNNTNTTTNCCCTNCCNCTCCACCNTNTNCNNCANANCNNNCCACNGNCNAT
NNTCNNANNCNCNCNTCNTNANCCTTNTCTNATNTNCNCNNCCNCNCANTGNCANCCCNCNNTCCNNANCNACNNNAC
NCNATNTCANTCCCNATTNNCNCCNNANNCCCNNACAGACCNGANTNTTCNTAANNGCCNNACNCCTGTNCCCNGCNN
NTNCNNANCTTNNNATNTTT

Endophyte: 94
GTCNGTCTGAGAGTTGANTCATTTNGGGCGTANN***GGACTCGTAGGCGGTTTGTNGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGG
TTTCNGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTANACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGG***NA
ANTGTTGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNCNNCNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNAGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNTN

Endophyte: 95
CCTCGGTCCNGAGNGTTGCGGCATTATTGGGCGTAAAGAGCTCGTANGCGGNTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCNGGTG
GAATGCGCCAGATATCAGGGAGGGAACCACCCGGATTGGCCGAAAGGCAGATCTCTGGGCCGTAACTGACNCTGNAG
GAGCGAAAAGGGTGGGGAGCAAACAGGCTTAAATACCCTGGTATCACCCGTAAACGTTNGGAACTNNTTNNGGGGGA
CCNNTTCCNCGGGTTNCCCGTGNNCCCANCCTTAACCCCCNNTAAATTTTCCCCCCCCCTNGGGGGGANTTNNCGGGCC
CCNNAAGGGGTTTAANAACTNTNAAAAAGGGANAAATTNGNCCGGGGGGAACCCCCCNCNNNNAAACCNCCC***NNN
NNNNNNNNNCNNTNNNNANTTTTNATTTTCNTTNNNTNNNNNCCNAAAAAAAANCCTTTNNCCCCNGANGGGNTTNTNN
NNNTTNTNTNCCNAAANNNNNNNNNNCCNNNNNNNNANAANGGGCNNGGNNNAGGGGNNNNNNANTGGGGAANGGA
GGNTGNGGGGGNNNNTNGGGGNNTNNNNNNNNTATATAANAATTTNNNNNCNCNGNNCTCNNNNNNNNNNNNNNNN
NNNNNNCCNNNNNNNNNNNNNNNNNNNNCNNNNNTNNNNNNNNNCNCCNCCNNNNNNNTNNNTNNNNNNNNNNNN
NNNNNNNNNNTTNNNTNNNNNNTNTNNNNCNNNNNNNNNNNNNNCNNNCNGCCGCTTTNNNNNCCNNCTTCANNCCC
CNNAAAANNNNNN

Endophyte: 96
NN***AGGGGCTNACATTGTNCGGATTACTGGGCGTAAAGCGCACGTAGGCGGCTTTGTAAGTTAGAGGTGAAAGCCTG
GAGCTCAACTCCAGAACTGCCTTTAAGACTGCATCGCTTGAATCCAGGAGAGGTGAGTGGAATTCCGAGTGTAGAGGT
GAAATTCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCGGCTCACTGGACTGGTATTGACGCTGAGGTGCGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATAACTAGCTGTCCGGGCACTTGGTGC
TTGGGTGGCGCAGCTAACGCATTAAGTTATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGG
GGGCCTGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCGTTTGACATGTCCGGTT
TGGTTTCCAGAGATGGATTCCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGGNA
AA***NNNNTGGNNNNAANGNNNNNNNNNNTGNNGNNNNNNANANNNNGNGNGCGNNNNNGNGNNNCNNCNCNCNN
GNNNNNNCNGNNANNNNNGNNNCNNNNNNNNNNNNNNGCCNNNNNNNNNNNNCNNNNCNGNNCNGNNCNNANNGNN
NNNNNGNNCCNNNNGGNGGNGNNNNNNANANNNANNCGGNGNNNAGNNCGNNCNANNNANNNGGNCCNNNNNTCG
CCTTNNTNNNCN

Endophyte: 97
CGCTCNGTCNTGAGNTGTTGCNNCATTATTGGGCGTAAAGGAGCTCGTANGCGGNTTGTCGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCNAAGAACCTTACCAAGGCTTTGACATA
TACGAGAACGGGCCANAAATGGTCAACTCTTTGGGACACCTCCGTAAACCAGGTTGGTGCATGGTTGTCGTCANCTCGN
GTCGTGAGAATNTTTGAGNTGNTAA***NNNNGCCTTNNTCCNCTCNANTCTTCCNNANTNTNNTTNNTTNCTATNNNNT
CNNTNNNNCNTCTNNCCCNNTTTNNCCGATNTTATNCTCCNCCCTCTNANCNANNNGCNNNNTCATNCGNCTATTNNNG
ATTGNCNNTNTATNCGCTCCTNNTTNNNCTTGTCATAGTTTTTCCNNCCTATTTTTANTNTNTCNNATANNNNNATTNCC
CCNNCACTNTCNNTCNTGNNTNTNTTNNNTCCCCCCNNTNNNCNCCNTNGTTNNCNNN

Endophyte: 98
TNCGCTCNGTCCTGGAGNGTTNGCGGNATTATTGGGCGTAAAGGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAAT
CCCGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAG
CGGTGGAATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTNGANNGCTTGAGG
AAGCNGAAAGGGGTGGGGAGCAAACAGGCTTAGATACCCCTGGTAGTNCACCCGTAAACGTTGGNACTANTTGGGGG
GACCATTCNNGGTTTCCGTGACCACNTACNCNNTNAAGTTTCCCCGCCTTGGGGGAANTCCGGGCCCCNAAGGGCTTA
AAAANNCNNAAAAAGGGAATTTNNACGCGGGGGGNAACCCCCCNNANAAAAACCCGGGGNGGGGGNNNCCCNTTNC
NGGGTTTNAATTTCCNANGNGCNNCCCGCAAAAAANNCNCTTNCCCAAAGGGTTTTGGACAATTTTTCCAAAAAAAAN
NCGGNNCCCNAAAAAAATNGGGGCCAANCTTTTTTTTTTGNNNNNCANTNNAANAGAAGGAGAANGGGNCNNNNANG
GNNCNNNCAGNANCCCGNCTTNGGAANGANNNNTNNNANAAANNNNNATATANNNAACTNNTTNCNCTNNANATTCN
CTNNCCCTNTCNCCCCNCNTNCCNNNTCCNCNCNCCCNANTCTATNNNNCGCNATTCNNNNNCNCNNCGCCANTACTT
GCGTANNTTTNNTATANTTNNGCNTNNNTTNTTNTCTTTNTNCTGTTNCNTTTTTTCNTCCNCATTTNNNNCCNNCCTATT
TTTNNANNCNCCNCATNNTANNCCNNNNNTNNAC***NN

Endophyte: 99
CTNGNNCCTAGCGGTTTGTTCGGCATTACTGGGCGTAAAGGGAGCGTAGGCGGGNCATTTAAGTCAGGGGTGAAATCC
CGGGGCTCAACCTCGGAATTGCCTTTGATACTGGGTGTCTTGAGTATGAGAGAGGTGTGTGGAACTCCGAGTGTAGAGG
TGAAATTCGTAGATATTCGGAAGAACACCAGTGGCNGAAGGCGACACACTGGCTCATTACTGACGCTTGAGGCTCGAA
AGCCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATTGCTAGTTGTCGGGATGCATG
CATTTCGGTGACGCAGCTAACGCATTAAGCAATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGA
C***GGGGGCCCCCACANGCGGGGGAGCATGTTTTTTTTTTNGAAGCANCGCGCATTACCTTTTTTTTTTTTTGACATGCC
CCGGAGGNGGNNGGNNTTTTTTTTTTTTTTTTTNANAAAAAAAANNAAAAAAGGTGCNTGCCCCCCCTTTNNNGCGGGG
GGGGNGNGGGGGAANATTTTNTCCCCCCCNNTTTTTTTTTTTCGGGGGGGNGNGGGGNNANANANNNNNNNNNNNNN
NTTTTTTTNNNNGGNNGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 100
GTCTAACAGGTAGCCGTAAGCTTGGTACCCGGGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACG
GTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACG
AGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAG
ATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACT
GCCGGGGTCAACTCGGAGGAAGGTGGGGATGACGTCAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACAA
TGGCCGGTACAAAGGGCTGCAATACCCGTGAGGTGGAGCGANTCCCCAAAAGCCCGGTCCCAAGTTCGGATTGAGGTC
T

Endophyte: 101
GGNGGGGCTAGCGTTGTTCGGATTACTGGGCGTAAAGCGCACGTAGGCGGCTTTGTAAGTTAGAGGTGAAAGCCTGGA
GCTCAACTCCAGAACTGCCTTTAAGACTGCATCGCTTGAATCCAGGAGAGGTGAGTGGAATTCCGAGTGTAGAGGTGA
AATTCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCNGGCTCACTGGACTGGTATTGACGCTGAGGTGCGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATAACTAGCTGTCCGGGCACTTGGTGCT
TGGGTGGCGCAGCTAACGCATTAAGTTATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGG
GGCCTGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCGTTTGACATGTCCGGTTT
GGTTTCCAGAGATGGATTCCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGGNGAAAAA
AAA***NNTNNGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 102
GCTCNGTCCNGAGNGTTGCGGTATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGG
ATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTGGAAAAA
ATTTTGG***NCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNAGNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 103
AAGGNGCTAGCGTTGCTCGGATTACTGGGCGTAAAGGGAGCGTAGGCGGACATTTAAGTCAGGGGTGAAATCCCGGGG
CTCAACCTCGGAATTGCCTTTGATACTGGGTGTCTTGAGTATGAGAGAGGTGTGTGGAACTCCGAGTGTAGAGGTGAAA
TTCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCGACACACTGGCTCATTACTGACGCTGAGGCTCGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATTGCTAGTTGTCGGGATGCATGCATTTCGGT
GACGCAGCTAACGCATTAAGCAATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGGGGCCC
GCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCACCTTTTGACATGCCTGGACCGCCA
CGGAGACGTGGCTTTCCCTTCGGGGACTAGGACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGANAAAAANTTG
G***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 104
GGGGCTAGCGTTGCTCGGATTACTGGGCGTAAAGGGCAGCGTAGGCGGNCATTTAAGTCAGGGGTGAAATCCCGGGGC
TCAACCTNGGAATTGCCTTTGATACTGGGTGTCTTGAGTATGAGAGAGGTGTGTGGAACTCCGAGTGTAGAGGTGAAAT
TCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCGACACACTGGCTCATTACTGACGCTGAGGCTCGAAAGCGTGGG
GAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATTGCTAGTTGTCGGGATGCNTGCATTTNNGTG
ACGCAGCTNACGCATTAAGCAATCCNCCTGGGGAGTACNGNCGCAAGANTAAAACTCAAAGGAATTGACGGGGGCCC
NCACAAGCGGNGGAGCATGTGGTTTAATTCGAAGCAACGCNCAGAACCTTACCACCTTTTGACATGCCTGGACCGNCA
GAGAGATCTGGCTTTCCCTTNGGGGACTATGACACANGNGCTGCATGGCTGTCGTCANCTCGTGTCGTGANANGTTGGG
TTAAGTCCCGCAACGAGCGCAACCCTNNCCATTNNTTGCCATCATTTANTTGGGAACTCTNATGGGACTGCCGGNGCTA
ACCCGGAGGAAGGTGGGGATGACGTCAAGTNCTCATGGCCCTTACAGGGNGGGCTACACACGTGCTACNATGGCGACT
ACAGAGGGTNNATCCTTAAAAGTCGTNTCAGTTCGGATNGTCCTCTGCNACTCGAGGGCATGAAGTTGGAATCGCTAGT
AATCGCG

Endophyte: 105
TAGGGTGCAAGCGTTAATACGGCATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGTTGTGAAATCCCC
GGGCTCAACCTGGGAACTGCATCTGTGACTGCATTGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGT
GAAATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACT
CAGTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGG
GACCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAAT
TTGCCAGAGATGGCTTAGTGCTCGAAAGAGAGCCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGAT
GTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTGTCATTAGTTGCTACATTCAGTTGGGCACTCTAATGAGACTGCCGG
TGACAAACCGGAGGAAGGTGGGGATGACGTCAAGTCCTCATGGCCCTTATAGGTGGGGCTACACACGTCATACAATGG
CTGGTACAAAGGGTTGCCAACCCGCGAGGGGGAGCTAATCCCATAAAACCAGTCGTAGTCCGGATCGCAGTCTGCAAC
TCGACTGCGT

Endophyte: 106
CGGTGCANGNGNNCTGGGATTACTGGGCGTAAAGCGTGCGTAGGTGGTGGTTTAAGTCTGTTGTGAAAGCCCTGGGCT
CAACCTGGGAATTGCAGTGGATACTGGATCACTAGAGTGTGGTAGAGGGTGGCGGAATTCCCGGTGTAGCAGTGAAAT
GCGTAGAGATCGGGAGGAACATCCGTGGCGAAGGCNGGCCACCTGGGCCAACACTGACACTGAGGCACGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTTCAACTTGGAACC
CAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGG
GCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATCCACGGAACT
TTCCAGAGATGGATTGGTGCCTTCGGGAACCGTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGT***NGAAAANA
NNTNGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 107
CGNTCNGNTCGTGANANGTTGACTCNTGTCGTGANNGTTGANCTCGTGNCGCGGATTGTNGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCNCACCATATCAGGAGGAACACCGATGGCTGAAGGCAGATCTCTGGGCCCGTNACTGACGCTGAGGAGCGA
AAGGGTGGGGAGCAAACANGCTTACATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTANTTGTGGGGACCATTC
CACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACNGCCGCAAGGCTAAAACTCANAGGAAT
TGACGGGGACCCTCACAAGCGGCGGANCATGCCGATTAATTCCATGCAACCNCGAAGAACCTTACCAAGGCTTGACAT
ATACGAGAACGGNCCCANAAATGGTCAACCTACTTTGGACACTCCCNAAACANNGNGGNGCNTGGCNGNCACNANCT
NGTGTCGTGANAATGNGTGGCANCCCTTNCCNCANNTNACNATNTCTATATNNTNAGANNNTGTCCACCNCTCNNNAN
CNCCCTNNTNTTATNTACANCATTNANTNCATNNNTCNTNTTNNCNCCTANCCANCNCCTTCNCNNNCTTTNTNATACA
NTANTTNTTGNAANANANTATTTANNTTNCCNNNCTNCCTNCNNTTACNTTNNNTACGCCCNNCAANNCTCACCCCNCT
NNNNCCNCNNNCTCCTTCTC

Endophyte: 108
CTCTGTCGTGAGNGTTGNNNN***TTATTGGGCGTAAAGGAGCTCGTNTGCGGATNGTNGNGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCAC
GGATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
GAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGA*
**NATGTTGNCNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNTNNNNNNNCNNNNNNNNNTNNNNNNNNNNNNNNN
ANNNANNN

Endophyte: 109
GTCNNCACGGTNGCCGTAGCTTGGCTGNNNGGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGTTGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATCTGTGACTGCATTGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGA
AATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCA
GTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATTT
GCCAGAGATGGCTTAGTGCTCGAAAGAGAGCCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATG
TTGGGTTAAGTCCCGCAACGAGCGCAACCCTTGTCATTAGTTGCTACATTCAGTTGGGCACTCTAATGAGACTGCCGGT
GACAAACCGGAGGAAGGTGGGGATGACGTCAAGTCCTCATGGCCCTTATANGTGGGGCTACACACGTCATACAATGGC
TGGTACAAAGGGTTGCCAACCCGCGAGGGGGAGCTAATCCCATAAACCAGTCGTAGTCCGGATCGCAGTCTGCAACTC
GAC

Endophyte: 110
TAGGGCGCAGCGTTTCCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCT
CAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAAT
GCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGGTGG
GGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTC
CGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAAC
GGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGATGTTG
GGTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACTGCCGGG
GTCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACAATGGCC
GGTACAAAGGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGAGGTCTGCAACCT
CGACCT

Endophyte: 111
GCTCGTGTGCGTGAGNAGTTGCNNCATTACTGGGCGTNAAGGGAGCGTAGGCGGACATTTAAGTCAGGGGTGAAATCC
CGGGGCTCAACCTCGGAATTGCCTTTGATACTGGGTGTCTTGAGTATGAGAGAGGTGTGTGGAACTCCGAGTGTAGAGG
TGAAATTCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCGACACACTGGCTCATTACTGACGCTGAGGCTCGAAAG
CGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATTGCTAGTTGTCGGGATGCATGCAT
TTCGGTGACGCAGCTAACGCATTAAGCAATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGG
GGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCACCTTTTGACATGCCTGGA
CCGCCACGGAGACGTGGCTTTCCCTTCGGGGACTAGGACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGGAAAA
ANGTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 112
CGAGGGGGCTNACNTTGTTCGGATTACTGGGCGTAAAGCGCACGTAGGCGGCTTTGTAAGTTAGAGGTGAAAGCCTGG
AGCTCAACTCCAGAACTGCCTTTAAGACTGCATCGCTTGAATCCAGGAGAGGTGAGTGGAATTCCGAGTGTAGAGGTG
AAATTCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCNGGCTCACTGGACTGGTATTGACGCTGAGGTGCGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATAACTAGCTGTCCGGGCACTTGGTGC
TTGGGTGGCGCAGCTAACGCATTAAGTTATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGG
GGGCCTGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCGTTTGACATGTCCGGTT
TGGTTTCCAGAGATGGATTCCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGTAGCTCGTGTCGAAAA
AAA***NNNTTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 113
N***CTCNGTCGTGAGNGTTGAGNCTTTTGGGCGTAAAGAGCTCGTGTGCGGATANNTNNGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCAC
GGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
GANAACGGGCCAGAAATGGTCAACTCTTTGGACACTCNTAAACAGGTGGTGCATGGNTGTCNTCAGCTCGTGTCCCGA
NATGTTGCCCCNCCCTTNTCNTNCNACCCANNCTCTCCCTCCTTACNNANNTCANNAATNCATNANCTNNACCCNCCAN
CCTANNTANCCTCCATTCNATATCTTTNNTCNCACNTCCNTNNTC***NNNNCNNNATCCNCCNCNCCCCCNAGATTNNN
NTNTNNCTTNTNTNCCNGNTNTTCCCNNCTTACANNATTCANGNANCTTGANNNCNTNTCCNNANNCACCATANCNNN
GNCGTCTNNTANNATGTTTN

Endophyte: 114
AGTCTACCNGGGNAGCCCGTANGNNTNGGGTNNCCCGGGGAAAGTCGTAACAAGGTAGCCGTAAGCTTGGATCCNGG
AAATCCCNNAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGG
TGTAGCGGTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGG
AGCGAAAGGGTGGGGAGCAAACAGGCTNANATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTC
CATTCCACGGATTCCGTGACGCAGCTAACGCATTAANTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAA
GGAATTGACGGGGACCCGCACAAGCGGCGGANCATGCNGATTAATTCGATGCAACGCNAAGAACCTTACCAAGGCTTG
ACATATACNANAACGGGCCAGAAATGGTTCAACCTNTTTTGGACACTNGTAAAACAGGTGGNGCCATGGTTGNNAATC
AGCTNNGTGTCGTGNANATGNNTGGGNTAANTCCCNCAACNAGCNCAACCCTNGTTCTATGTTNCCANCACGTAATGG
AGNGAACCTCATGGGGATACTTGNCGGGGTCCAACCTCNNANGAANGTNGGGGATTNACCTTCAAATNATCNTNCCCC
CTCATGTCCTTGGGCNTCTANNCTTAGCTACCAATGG***NNNNNNTCAAANGGCCTNCANTACCNCCCANGTTGCAGC
NANTNCTAAAAANTCTCGTCCCAACTNCGGATNNNGGTNTNNANCTNGACCCTATN

Endophyte: 115
TGNTCNNGTCTTGAGTATGTTGGGNATTACTGGGCGTAAAGGGAGCGTAGGCGGACATTTAAGTCAGGGGTGAAATCC
CGGGGCTCAACCTCGGAATTGCCTTTGATACTGGGTGTCTTGAGTATGAGAGAGGTGTGTGGAACTCCGAGTGTAGAGG
TGAAATTCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCGACACACTGGCTCATTACTGACGCTGAGGCTCGAAAG
CGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATTGCTAGTTGTCGGGATGCATGCAT
TTCGGTGACGCAGCTAACGCATTAAGCAATCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGG
GGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCACCTTTTGACATGCCTGGA
CCGCCACGGAGACGTGGCTTTCCCTTCGGGGACTAGGACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGAAAAA
NATTTGG***NNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 116
GTCNGTCTGAGAGTTGNGGATTTTGGGCGTAAAGACTCGTANGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCTCA
ACCTCGGGTCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAATGC
GCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTTACTGACGCTGAGGAGCGAAAGGGTGGGG
AGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGGATTCCG
TGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGACC
CGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAACGG
GCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTNAGATGTTGAC
CACC***NNNNNNNCNNNTNNNTNNCCTNACNANCNCNCTTTCCTCNTNCNNNNNTNTNCNNCNCCTCNACNNNCNNNC
NNGCTCCTNNTNCATNANNNCNNCNNCTTNTNTGNCTTTATTNCNTNNNNACNTNNNTNTATNTTNNNCTTNNNCCNCN
TNCCNCNNCCANNTCNACTNTNTTNTNCCCACCCCTNCNNNNCCNNNTTNNNTNTNTTTTN

Endophyte: 117
TGCNCGNGNCNTGAGGTNGTNNCTCGTGTCGNGAAAGTTGGCTCGTGTNCGGAAATGTTGGGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCANACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCANATCTCTGGGCCNTAACTGACGCTGAGGANCNAAA
GGGTGGGGAGCNANCAGGNTTAGATACCCTGGTAGGTCCACCCCGTAAACGTTGGGAACTATNTTGTGGGGACCATTC
CACGGACTTCCGTGANGCNNCTAACNCATTATNTTCCCCGCNTGGGGAGTACGGNCGCNAGGCCTAAAACTCAANNGA
NTTNAAGGNGACCCGCNCCACCNNGCGGNCCATGCTTNNTTAATCCNATNCAACGNNGAANAACCNTNCAATGCTTGN
CATATNCCGATNANCNGTNCANATTTNNACCCCCTNTTTGGNACACNNNTNNTTCNTGTGGATNCATAGNCATGTNNNN
AAGNTTTTTNTCNCCTAACAGNNTTTNNCTCNCNCNCCCNATTANNTTTTTTATNCTCTTTNCCNCTCCTTTNACACAAC
TNTTCCTCNCTNTNNNTTNTNCTNTANTGTNNNGTCTCTCNTCTCNNATCNNA***NNNNNNTTTNCATCNTNNCTNNTC
NNTTNTACGNNAANAGNCACNNNTGNATTNTNTCTCCCCNTNANCNNNCNCNCCNTCNTTCTCCTTNTTTCATCCNACT
CGTNANNNTTTGNTCNNCAANNGATNTNTNNTATNCCCCTCATATTTAATTNTNNTAAACATNAAANNTNTNTAGNCGT
TNAT

Endophyte: 118
GGTGCAGCGTTAATCGGAATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCGGGCT
CAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGAAAT
GCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGTGGG
GAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCAGTA
ACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGACCC
GCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATCCTTT
AGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATGTTG
GGTTAAGTCCCGCAACGAGCGCAACCCTTGCCATTAGTTGCTACGAAAGGGCACTCTAATGGGACTGCCGGTGACAAA
CCGGAGGAAGGTGGGGATGACGTCAAGTCCTCATGGCCCTTATAGGTGGGGCTACACACGTCATACAATGGCTGGTAC
AGAGGGTTGCCAACCCGCGAGGGGGAGCTAATCCCATAAAGCCAGTCGTAGTCCGGATTCGCAGTCTGCAACTCGACT
GCGTGAAGTCGGAAT

Endophyte: 119
TTNNNCGTCTTCTGNGGGANNTGNNANTATTTGGCGTAAAGAGCTCGTANGCGGNTNGTCGCGTCTGCTGTGAAATCCC
GAGGCTCAANCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCGATGGCAAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGANNTTTTT
NGGTGGGGAGCAAACAGGCTTANATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCA
CGGNTTCCGTGACGCANCTAACGCATTAANTTCCCCGCCTGGNGAGTACGGCCGCAAGGCTNAAACTCANCAGGANTT
GACTGNNGACCCNCCCAAGCGGGTGNNCCNTNCTCGNNTAANCCTNTNCNNCANCGAANAACCCTCACCACTGCTCAN
NCCATNNTACNNANNANCTTGNCTCANTANACCGGCCCCGANCGNCTGNCACACTNCANANNANACNCCGNACGTNTC
NAACCCGTNTCCCANTCGTNGNNGTTNNNAAAATNTNGGTCNTGCNNCCTNCACCNTNNACCCNNTNCCNANACACAA
NNCCCNNTACNNNAACCNGNGACNNGTNNCNGCANGCAACAACNNTNGCCAGNNTNCNC*******NNNNCNNGNTNNNNA
NCANNTTNNCNNNCCNCCNANNAGCANNNNACTTANCTTCATANTCNACNGNCANNCCANACAAANNANNACNNACG
NAGAATNATTNTCCANNCNNNATNNNCCNTNTNNNNGCTCTCNTTTNNCNAANT

Endophyte: 120
CCTCNGTCTGAGTGTTGCGGATTTTGGGCGTAAAGGAGCTCGTANGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGC
TCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAA
TGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTG
GGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTT
CCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGG
ACCCGCACAAGCGGCGGAGCATGCGGATTAATTCNATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAA
CGGGCCANAAATGGTCAACTCTTTGGACACTCNTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGACAA*******N
NGTTGCCCNNTNCATCNNCCCCCCCNTNNCCNTCCANGCCCCANCATCTNCNATCNNNATNCCNCNNNATTNTNNCTTN
NTCATNTTCCTCNCCCNNNTNCATNGNNNCCNTCCNTNNNATATTCTNCCNNCNCCNNCNNATCANNCGNTNTCCNATN
NNNNNCNNNCANNNTNNTNATANNTTNNCNCANTNCNNATACCNNNNNNNCTNTTCCNTNATCTNTCTNANNATTCAN
CCCNCCCCCCNACTCNCTNTNNNNCNNCNCCCTTTTNNNTTTT

Endophyte: 121
CTNTGTCGTGAGAGTTNGTTGTTNCTGGGCNTAAAGCGCACGTAGGCGGCTTTGTAAGTTAGAGGTGAAAGCCTGGAG
CTCAACTCCAGAATTGCCTTTAAGACTGCATCGCTTGAATCCAGGAGAGGTGAGTGGAATTCCGAGTGTAGAGGTGAA
ATTCGTAGATATTCGGAAGAACACCAGTGGCGAAGGCGGCTCACTGGACTGGTATTGACGCTGAGGTGCGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGATAACTAGCTGTCCGGGGACTTGGTCTTTG
GGTGGCGCAGCTAACGCATTAAGTTATCCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGG
CCTGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCGTTTGACATGTCCGGACGA
TTTCCAGAGATGGATTTCTTCCCTTCGGGGACTGGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGGGAAAAA
TGTTTG*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 122
TCNGTCGTGAGANGTTGANTCTTNTTGGGNGNNNAGAGCTCGTNTGCGGATNGTNGNGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTANAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTACCAGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCNGAANGCAGATCTCTGGGCCGTAACCTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTANATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTANTTGTGGGGACCATTCCAC
GGTTTCCTNTGACNCAGTTAACGCATTAANTTNCCCGCCTGGGGAGTACGGCCNCNAGGCTAAAACTCAAATGAATTG
ACNGNGACCCNCCCAAACGGTGGAGCATGCGNATTAATTCTATGCAANTCNAANAACNTTACCAANGCTNNNCATTCT
ACCANATCNGANNCNTAAATGGGTNNACATATTTNGACACTCTNCNANNCGNNGGNGNATNGCTNGTNATNCCCTCNT
CTCNTNANGATNCCCGACNCANCANCCTNCCATATNCTCANNTCCNCTTNTTCNNTCACCTNNNCCCTATATTNTTNGN
CANNNGGNACANCNCTCGTTCCNGNANTNAGCTNTCANCNACNNNTATATAATNNNTCTCGTCNCANNATTNANNTCC
ANNNTNCNNTCNNTACCACNACNNATNTANCNTCTANCNATTCNNGNCNNCTCNCACTNNATACNCNANAANAAANN
ATACACNNTCANNCNTTACGNNAGATNNCNNCNCNNCNTATANATNTNNATANANT

Endophyte: 123
CTCNGTCGTGACNGTTGACTCATCCTGGGCGTNNAGGGCGCGTAGGCGGACTCTTAAGTCGGGGGTGAAAGCCCAGGG
CTCAACCCTGGAATTGCCTTCGATACTGAGAGTCTTGAGTTCGGAAGAGGTTGGTGGAACTGCGAGTGTAGAGGTGAA
ATTCGTAGATATTCGCAAGAACACCAGTGGCGAAGGCGGCCAACTGGTCCGATACTGACGCTGAGGCGCGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGCCAGCCGTTGGGGTGCATGCACTTCA
GTGGCGCAGCTAACGCTTTAAGCATTCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGGGGC
CCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCTTTTGACATGTCCGGTTTGAT
CGACAGAGATGTCTTTCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCNTCAGCTCGTGTCGTGA***NN
ATGTTCGNCCNNTCCCCCCCTTNTCCTNNNTGNNCCTTCNTCACCCACCNTNNCCNNAANNCTNCNTACANACNTTNGN
NACAGNNNCCCNNTNNCNNCATNCCNCNNNCGANCTTCCNNCNNCCNCCGNTNTTNTNNCNNTGCCNCTNGNCNNNCN
CCANNTTNNCTCGCGCNTNNNNCTTTNNCTNCTCCCCCCNTAATCANANCGNNANANAANTTCANCCCCCCCCNNCCC
ANTNCCCNCTACNNCNCACTANA

Endophyte: 124
CTCTGTCTGAAAGTTGNCTCATCCTGGGCGTNNAGGGCGCGTAGGCGGACTCTTAAGTCGGGGGTGAAAGCCCAGGGC
TCAACCCTGGAATTGCCTTCGATACTGAGAGTCTTGAGTTCGGAAGAGGTTGGTGGAACTGCGAGTGTAGAGGTGAAA
TTCGTAGATATTCGCAAGAACACCAGTGGCGAAGGCGGCCAACTGGTCCGATACTGACGCTGAGGCGCGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGCCAGCCGTTGGGGTGCATGCACTTCAG
TGGCGCAGCTAACGCTTTAAGCATTCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGGGGCC
CGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCTTTTGACATGTCCGGTTTGATC
GACAGAGATGTCTTTCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGAAAT
GTTTGG***NNNNNCNNNNNNNNNNNNNNNNNNNNNCNCNNNCNNNCNNNNNNNTNTNCNNNNNNNNTNNNNNNNN
CTNNNCNNNNNNNNNTNNNNCNCNNNNNNNNTNCNNCNCNNNCNNNNNCNNNNNNNTNNNCCCNNNNNNCNTNTC
NCNNNNNNNTNNNCNNNCNNCNNCNNNTNCNCNNNNNNNNNTNNNNNNNNTNNNNNNNNNNCNNTNNCNNNNNNC
NNNNNNCCNNNTNNTNTN

Endophyte: 125
TTNACTAGTTGCCTCNGTGCTGAGAGTTGCGNCATCACTGGGCGTAAAGGGCGCGTAGGCGGACTCTTAAGTCGGGGG
TGAAAGCCCAGGGCTCAACCCTGGAATTGCCTTCGATACTGAGAGTCTTGAGTTCGGAAGAGGTTNGGTGGAACCTGC
GAGTGTAGAGGTGAAATTCCGTAAGATATTTCGCAAGAAACACCAGTTGGCCGAAGGCGGCCAACTGGTCCGATACTG
ACCCTTAAGGCCCAAANCNTGGGGAACAACAGATAATNCCTGGTANCCCCCCGTAACAATNATGCCACCCGTTGGGGT
GCNTTGCCCTTTNANTGGGGCCCANCTTAACNCTTTTAANCCNTTTCCNCCTNGGGGGNATTCCGGGGC***CCCCAAAA
AANTTATAAACCCCTCCAAAANGGGANATTTTTTNNNNGGGGGGGCNCCCCCNNCCNNNNNNNGNGNGGGNNGNNCC
NGGGGGGNTTTAAATTTTNNNNNNNNNNNNGGACCNNNAAAAANNNCNNTANCANACNNTTTTNNNNNNNNNNNNNN
NNNNNNNNNTAAGTNNNNCAANNNNNNGGAGGTNNNNNNAGTNNGAGTNTCCGATGGGTNNNGNGNNNNNNNNNNN
NTNTTATTTTNNNNANNGGGGGNTCTTNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNAG
TNNNNNNNNNNNNNNNNNNNNNNNNNAAANNNN

Endophyte: 126
CCTCNGTCTGAGAGTTGANNCATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGA
AATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCA
GTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATCC
TTTAGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGAAT
GTTGAC***NCNNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNANNNNNNNN

Endophyte: 127
ACGGTGCAGCGTNNTGCGGATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCGGGC
TCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGAAA
TGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGTGG
GGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCAGT
AACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGACC
CGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATCCTT
TAGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGNAAAAAATN
TTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 128
AGGGTGCAAGCAGTTAATCGGATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGA
AATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCA
GTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATCC
TTTAGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTTGAGAAAAANN
TTNGG*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 129
CTCGGTGCNGAGATGTTGCGGATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGTTGTGAAATCCCCGG
GCTCAACCTGGGAACTGCATCTGTGACTGCATTGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTGA
AATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTCA
GTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATTT
GCCAGAGATGGCTTAGTGCTCGAAAGAGAGCCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGNNAAAAAA
NGTTGG*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 130
CCTCNGTCGTGAGNGTTGAGNNATTACTGGGCGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGTGAAATCCCCG
GGCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCGTGTAGCAGTG
AAATGCGTAGATATGCGGAGGAACACCGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCATGCACGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGTCTTCACTGACTC
AGTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGGAATTGACGGGG
ACCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGACATGTACGGAATC
CTTTAGAGATAGAGGAGTGCTCGAAAGAGAACCGTAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTNAGAA
TGTTGG*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNN

Endophyte: 131
CTCNGTCTGAGNGTTGNGNATTTTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCTC
AACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAATG
CGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTGGG
GAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTCC
GTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGAC
CCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAACG
GGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGG*******NNAATGTT
GGNNNNNNNNNNNNNNNTNNNNNNNCNNCNCCNNCNCNNANNNNTTNNNNNNCNNNNTNNNNNNNNNCNNCNNNNCN
CNNCTTCNNCNNNNNNNNNNNNNCCNCNTCNNNNNTNNNNTCNNNNNNTCNNNNCNNCNNNNCNNCNNNANNNNNN
NNNNNNCNNNTNCNCCCNCNNTNNNNNNNNNNNNNNNNNNNNNNNCCNCNNNCNNNTNNNNNNNCCNNNNNNCCNNN
TNTNTNN

Endophyte: 132
AGNNGTACCTGCTGGNNCGNCGGNNNNCGATNGTTCNNGGGAANTAACAAGGAAGGCGTAAGCTTGNTTNCCTNCAG
GCCCNNCTCTCAGGGTCNGGCCTGCAANNAANTACANGGCATTACTAGAGTGAGGNAGGGGAGAATGGAATTCCTGGT
GTAGCGGTGGAATGCTGCANATATCANGAGGAACACNNGATGGCGAAGGCAGTTCTCTGGGCCGTAACTGACGCTGAN
GAGCNAAAGCGTGGGGAGCGAGGNGGATTAGATACNCTGGTAGTCCACNCNGNAAACGTTGNGCCNCTANATGTGGG
GACCATTCCACCGGNTNTCCGTGTCNCANCNAACACATTAAGCNCCCCNCCTGGGGAGTACGGNTTNTAAGGNTAANA
CCTCAAAANGAATCCNACNGNGGNCNCGTANAATTCNNNTNCCANNATNNCCGNTTTAATTCNAATCCANTTAACGNC
AACCTTTNANNAGGGNCTTTGACCTTANANANAGAACNNNTNCNANNANNATAANGGNNNNTCTTNTGTACNNCTCAN
TNATACTNAGNNNNTGCNTNGNATNNTTNATAAGCCNCGTNGTCCNANAACANAANNGNNNCTAACATCNCCNCAAN
CCAANCNCNANCNCNNANNTTNTNTGANAGTNANACGNCNNCANNGGNNGTGNNNCTNATNACGNATCCCTGTNNNG
TCATCAATNTNNCACGA*******NNNNGGTANTNTACNCTCANNNNNACCNTGCTCCANAANCANTCGNNCNNANCNNCCG
GTNNAAANNNNNNNAACNNCNNNTTNNNCACNAATGANTNNAGANNCCGNAACACTATAAACNNNANATCTNCNTCG
NNNNNATTNTNTNNCNNTNNNTNTNNTANA

Endophyte: 133
GTCGACANGGNGNCCTAAGCNTGGNTTGCCGCGGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCC
GGGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGT
GAAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAG
CGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGATGTCGATTTGGAGGTTGTGCCCTTGAGG
CGTGGCTTCCGGAGCTAACGCGTTAAATCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACG
GGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATCCACAG
AACTTTCCAGAGATGGATTGGTGCCTTCGGGAACTGTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAAA
TGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTATCCTTTGTTGCCAGCGGTNCGGCCGGGAACTCAAAGGAGACTGC
CAGTGATAAACTGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGACCAGGGCTACACACGTGCTACAA
TGGCATATACAAAGAGAAGCGACCTCGCGAGAGCAAGCGGACCTCATAAAGTATGTCGTAGTCCGGATTGGAGTCTGC
AACTCGACTCCATGAAGTCGGAT

Endophyte: 134
CTCNGTGCNGAGNGTTGCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGC
TCAACCTCGGGCTTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAA
TGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGCATG
GGGAGCGAACAGGATTAGATACCCTGGTAGTCCATGCCGTAAACGTTGGGCGCTAGATGTAGGGACCTTTCCACGGTTT
CTGTGTCGTAGCTAACGCATTAAGCGCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGG
GCCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATACACCGGAA
ACGGCCAGAGATGGTCGCCCCCTTGTGGTCGGTGTACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGG***NNANNT
GTTGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 136
CTCNGTCTGAGNGTTGCGNATTTTGGGCGTAAAGGAGCTCGTAGGCGGTCTGTCGCGTCTGCTGTGAAAACCCGAGGCT
CAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAAT
GCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTGG
GGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGGATTC
CGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATACACGAGAAC
GCTGCAGAAATGTAGAACTCTTTGGACACTCGTGAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGNAAAANGTT
GG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 137
TAGGGTGCAAGCGTNGTCCGGCATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCNGGCTTGCANTGGGTACGGGCANACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTTGGGCCGTAACTTGACGCTGAGGANCGAAAG
CATGGGGAGNGAACAGGATTAGATACCCTGGTANTCCNTGCCGTAANCGTTGGGCNNTAGATGTATGGACCTTTCCAC
NGTTTNCTGTGNCGTANNNANNCNCATTANNCGCCCTNTCCTNGTNNANTACNGGCCGCTAAGGTNTAANNCCTCANN
ANGGANTNTACCTATTGCCCCCCACNNTCTCGCNCTTCANGNCNATTTATTNCCGATGNCNACTCCNNTANNNCNNTNN
NTANAGGCNCCGNCTTNNNNCNNANAAAATNTNNTTNTNTTNNNNCACNCTATATTANANNCCNCTNNAACANANGTG
TGTCNCANNANTNNC***NNNNNTNANCNNTCTCANNNTCATNNATNNACNTTNGNNTATAATTNNCCTNNAACCNATN
TCTTTCNCCTNNCTTCTTATATATNNNNCCNGNNTNATANTNTNCNNNNTTTANANAAAGNTCCNNTNTGTNNANNTNN
NCNNANGNNATNNTTCTCNACTTNTNCNCCNNACCNNCCTCNNNCCTACATCTCNCCNAGNNTNNNTNNNNATNTATA
ANATTTNNCCATNTCNTANNTGTNNNCNTACNNCTCCATTNGTTNTTCCNTTCTCNNCTTATGNGCGNTANTATCGNTCT
CTN

Endophyte: 138
GGCACAGTNGTTATCCGCNTNNTTGCNCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCTC
AACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAATG
CGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTGGG
GAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTCC
GTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGAC
CCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAACG
GGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGATGTTGG
GTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACTGCCGGGG
TCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACAATGGCCG
GTACAAAGGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGAGGTCTGCAAC

Endophyte: 139
CTCNGTNCNGAGNGTTGCGGTATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGT
GGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGT
TTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGG
GGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAG
AACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGNAAAA
TGTTG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNN

Endophyte: 140
CTCNGTCTGAGNGTTGCGGNATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGC
TCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAA
TGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTG
GGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTT
CCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGG
ACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAA
CGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGNNAATGT
TTGA***NNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNN

Endophyte: 141
CTCGGTCCNGAGATGTTGCGGATTATTGGGCGTAAAGAGCTCGTANGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGT
GGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGGA
TTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGG
GGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAG
AACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGNAAAN
TGTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 142
TGCTCGTGTCATGGATAGTTGGGATTATTGGGCGTAAAGTAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCAC
GGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCNATGCAACGCGAANAACCTTACCAAGGCTTGACATATAC
NANAACGGGCCATAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCC***N
ANAANTNTTNGNCCCCACCNNTTTNNNNTTCNTCNNCNTNANTTAANNNNACNTNCTGTTNNCNNNTCNNGNNNTTNC
NTNNNTNNANNNATNTNTTNTTTTTNGNTCNNNCNNANATCTTNCTTNCTTCTNNCNCTNTNNNTANANNNNNNCNTNN
TATCTNCNAATCCCCTCACCTNNNNANANNNNNNTNATTNCNTTNTCCTNCCTNCNTCNNNTCTNGTNCNNCTNTTTTC
NNCCTTTTTCCTTTATNTNGTCNACCNANCT

Endophyte: 143
TAGGGTGCAAGCGTTGTCCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCGGCTGTGAAAGCCCGGA
GCTCAACTCCGGGTCTGCAGTCGATACGGGCAGACTTGAGTGTTGCAGGGGAGACTGGAATTCCTGGTGTAGCGGTGA
AATGCGCAGATATCAGGAGGAACACCGGTGGCGAAGGCNGGGTCTCTGGGCAACAACTGACGCTGAGGAGCGAAAGC
GTGGGGAGCGAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGTTGGGCGCTAGGTGTGGGGGCCATTCCACG
GTCTCCGTGCCGCAGCTAACGCATTAAGCGCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGGCCCGCACAAGCGGCGGAGCATGTTGCTTAATTCGATGCAACGCGAAGAACCTTACCTAGGCTTGACATGTGCG
GAAATCCTCCAGAGATGGTGGGTCCCGTAAGGGTCGCACACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCTGAAAA
AA***NTTNGGNANNNNNNNTANGCNTANATNNNCNNNATNCCGNNNGCNNNTNTTNNATNTTTANNNATNNNATNCT
CTCCCCNTNTNCCNNNTNCTNTGNTNNACATGTCTNNNAATATCCNCCNTGNTNNCANTTNCGNCTNNNNTCNNNNATN
NNGCNANNNNNNNCNNNCCNCNNANNTATCNNATNCNACCGNCNNGGCNNANNNNNNAANAACNNGNCGAAANGNN
NNCNCNNNNANACNCCCACNNANTTNNN

Endophyte: 144
CTCNGTCTGAGNGTTGCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCT
CAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAAT
GCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTGG
GGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGGATTC
CGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAAC
GGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGNAAANTGT
TGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNN

Endophyte: 145
N***TCGGTGCNGAGNGNTGCGGATTTTGGGCGTAAAGAGCTCGTNTGCGGATAGNNNNGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGG
ATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGNAAA
ATGNTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNN

Endophyte: 146
CCTACNGTCCNGAGNNNTGCGGTATTATTGGGCGTAAAGAGCTCGTANGCGGTTNGTCGNGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGNCAAGNACTAGNAGTCGCCGGTAGGGGAGNATTGGNAATTCCTGGT
GTAGCGGTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGG
AGCGAAAAGGGTGGGGAGCAAAACAGGCTTTAAGATACCCCTGGNTACTCCCCNCCCCCGTAAAAACCNTTGGGGGA
AACTTAAGTTTGNNGGGGGGNTCCCATTTNCCCACCGGGATTTCCNNTNGACGCCNAACTTAACCGCCATTTTAAANTT
TNCCCCCCCNCNCTTGGGGGGAANNTTACCCGGGCCCCGCCAANGGGGNTTNAAAAAACCTTTNNNAANGNGNAATA
NTTGACCCGGGGGGAACCCCCCNANCNANACCCAGGTGGGNAANGATAGCCNAGNATTTAAATTNNTCAATCCCNACC
CNCGAAAAAAACCNTTTTCCAAAGGGGTTTTTNAATNTATTNNNAAAAACCCGNCCCANAAAANNNGNCCAAANTTTT
TTTGNANCNNTNTTAAAANNGNGGNGGGNCTTGNTNNCNNNNNNCTCTCGNGTCNNAGAAAAANTNANCCCTACNTN
NNATNANTATNACNNNNGCGCNCNNCCNGCCGATTCCCNATTTATTTCTNATNCCNCNTTCNATTNCTNNNNNGTNCCC
CCTNTNACNNCTTTCTNNNTNTTNTAACNCNANTTAGNCNTNCATTNTTNNGCCCNCCCNNNANTNNGNTAANAANTAA
AANANAAANNNNCNCNNNCNANTNCCCNCTATTTNATANNNNNNCACNNTNACCNNATNNTANTTANC

Endophyte: 147
ANTCNACCANGTNNCCNTAAGNTNTNANACCNGGGAAGTCGTAACAAGGTAGCCGTAAGCTTGGATCCCGGGATCCCN
TTGTATCNGCNNNNGNGGTACAATGNNAACCGNCAAACTANAGTGCAGGAAGAGGAGATNGGAATCCCACGGNGTAC
CNNGNGGAATGCTNCATATATCAGGAGGAACACCGATGGCCAAGGCAACATCTCTGGNCCGTANCTTGACGCTNAGGA
GCAAAAGGGTGGGGANCNNNGNGGCTTACATACCCTGGTANTCCACCCCANAAACNNTGGGAACTAATTNTGGNGNN
CNTTCCTCGNATTNCNNGACCCCCCCACACCAATNANCCCCNCCNAATNNNNNNANTTACNATTNNAANANTTNACTT
CTCNNTNNAATTNATNGNGACCANATANCATNNNCNGNNCCNNNNNCACATNAANNNNANCCNCACCNNNAANNAAA
CNTAANCAAGTGNNTNANCATTTATNCANAATNCCTNCCGANCANNNNTNACTNCTTTGNNGCACTTNTTNNCCANNN
GNAGNCNNANCANGANCTTANCCNCCTTGTNCANAANAATNTTNGNNCTAAAGCANNCGNNACTANTCCTGNNCNCCC
CATNTTNTTCNNNCNNNANCTNCANANATNNGANCNCNATTTAATCNAAATCNTATCCTNANCTCAATCTNCNNGNCN
TNAANCTNACGCATNNCTCCNAAANTAANANNNANANNNTTNTAATCNNCCNCTNTTANTNANNACCNANCCCTACCA
TANNTAACNCTTTACCANNNATNANNTATANATACNCNANCNNNNATACTTCNATCTCCNNNGNGNNNTTACTTCTTNC
TNTNAANNNGCCNNACAAAG

Endophyte: 148
CGCTCNGTCGTGAGTGTTGCGGNATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACNGTTGGGAACTAGTTGTGGGGTCCATTCCAC
GGATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
GAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTNA
AAATGTTTG***NNATNATNNNTTCTNNNTATNCCNCNCCATTACTCACCANCACNNNNCCNNTCTNNANTCTCTNNNN
NCCCNNNCCCCCNANNNCCNNTANTCNGCNCCNNNGGCCNNNANNCCNATTNNCTNNTNTCACCANTTNNNNCACANT
TCCNCANANTTNTNTNCNTNTTCNNNATCTNTTTNNTTNTTNGTTTNNCTTTTCNNCAGNCCNGCCTNCTNNNCCCCCN
CCTTNTTTTCCCCCCNCTNCCCCCNAAANACNTNNAC

Endophyte: 149
AGNAANTACACGGTAGNTCAGTNNGCTTGTTTNCNNNNNAGGAGCTCNTAGGCGGTTTGTCGCGTCTGCTGTGAAATC
CCGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGC
GGTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGA
AAGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTC
CACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAAT
TGACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATA
TACGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGT
GAGATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGAT
ACTGCCGGGGTCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCT
ACAATGGCCGGTACAAANGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGANGT
CTGCAACTCGACCT

Endophyte: 150
GNTCNNGNTCGNGNNNGGTTGAGNCNGCNANCCGCNGNNNTAGACTCGNGTCGGGANATGTTGNCCCCCCNCCCNAA
ANNTTGNCCTCNTNTCGNNAANTNTACCNANTACTCGNCAGACTAGAGTGCTGGTANGGGAGATTGGAATTCCTGGNG
TNCCGGCGGAATGCNGCNNATATCAGGAGGAACNCCNNATGGCNAAGGCANANCTCTGGNCCGCAANTGNCNCNTGA
NGANCNAAAGGGTGGGGANCNNGNGNGGNCTTACATACCCTGGTNGTCCNCCCCGCAAACGTTGNGAACTATTTGNGG
GGNCCCTNCCACGGATTCCCNGACCNANNNNACGCATTAACCNCCTTCCTGGGGAGTACGGCCGNAGGNTAATACTAA
NTNGANTNGANGGGGACNCTCACAANCCTNTNGCCCATGCNGNTTAATTTTCATGCCANNCCGAAGAANNTTCACANC
AGCCNTTNCCTANTCNNGNACCNGCCCATACCNGGCCAACTTNNTATNNTACACNNGNTNNNNANTANNCGCAANGCC
NNACNTCCCNCNNCNGTNCCCCNANNGANCGNNANCCNCNTNTCTNGTGTNTNCCCNAGNNNCANCNNCACTNTNNTC
TATTNANTNATAANACGGATNNNAATTNTANCCCNACCACNNCAACGNTCCATNTATNNCCANCNTNCCTCNTTCNTCN
GCANCNNACTTNGNNCGTCTTATNNNNCTNNATNNNNGTNNATNCACNNNTCCNATCAANCCGATNNTNNTATNANAG
CAANTAACNANCNAACANTNTAATCNCNCANAGNNANNNNCTGTNTNATANTT

Endophyte: 151
CTACGGTGCTNACNTGTGTGCGGNATTATTGGGCGTAAAGAGCTTGTAGGCGGTTTGTCGCGTCTGCCGTGAAAATCCG
GGGCTCAACCCCGGACTTGCGGTGGGTACGGGCAGACTAGAGTGTGGTAGGGGAGACTGGAATTCCTGGTGTAGCGGT
GAAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGGTCTCTGGGCCATAACTGACGCTGAGAAGCGAAAG
CGTGGGGAGCGAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGTTGGGAACTAGGTGTGGGTCTCATTCCAC
GAGATCCGTGCCGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGGCCCGCACAAGCGGCGGAGCATGTGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATGC
GAGAACGCGGCAGAGATGTCGTTCTCTTTGGACACTCGTATACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTGGAAAA
NTNGTTG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 152
AGTCNANNAGNGNANCNNNTAANNCNTGNGTNNCCN***GGGCANNGGGTAACAAGGTAGCCGTAANCTTGGTTCCNG
GAAATCCCGAGGCTCAACCTCGGGCCTGCATTGGGTACTGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGG
TGTAGCGGTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGG
AGCGAAAGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGAC
CATTCCACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAA
GGAATTGACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCNATGCAACGCGAAGAACCTTACCAAGGCTTG
ACATATACGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGT
GTCGTGAGATGTTGGGTTAAGTCCCGCAACGAGCGCACCCTTNTTCTATGTTGCCAGCACGTAATGGTGGGACCTCATG
GGATACTGCCGGGGTCAACT***NGGANGAANGTGGGGATGACNTCAAATCATCATGCCCCTTATGTCTTGGGCTTCAC
CATGCTACNATGGCCGGGTACAAAAGGCTGCACTACCNTGAAGTGGAGCGAATTCCAAAAANCCGGTCCCANNTNGGA
TGGAGGTCNGCAACTTGACCNCATGGAAAT

Endophyte: 153
CTCTGTCTGACTGTTGCGTCTTTATTGGGCNTAAAGAGCTCGTAGGCGGTTTGTCGCGTCGGCCGTGAAATCTCCACGCT
TAACGTGGAGCGTGCGGTCGATACGGGCAGACTTGAGTTCGGTAGGGGAGACTGGAATTCCTGGTGTAGCGGTGAAAT
GCGCAGATATCAGGAGGAACACCGGTGGCGAAGGCNGGGTCTCTGGGCCGATACTGACGCTGAGGAGCGAAAGCGTG
GGGAGCGAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGTTGGGCGCTAGGTGTGGGCGACATCCACGTTGT
CCGTGCCGTAGCTAACGCATTAAGCGCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGG
GCCCGCACAAGCGGCGGAGCATGTGGATTAATTCGATGCAACGCGAAGAACCTTACCTGGGCTTGACATGCGCCAGAC
ATCCCCAGAGATGGGGCTTCCCTTGTGGTTGGTGTACAGGTGGTGCATGGCTTGTCGTCAGCTCGTGTCGTGAAANTGT
TNGC***NNNNNNNNCNNCCNCNNNNNNNNNNNNNNNCTNNCTNCGCCNNNNNNNANNNNNNTNTNNNCTNNTTNNCT
CNNNNCNNNCACNNNNCNCCNNNNNNNCNNCNNCCCCNCCNTCNTNCTCCNCNNNCCCCNCCTCCNNNCNATNNNNC
NNNNNNNNNNNNCCCNCTNCNCNNCTTNNNNNNNNNCNNNNNNNTNNNNNNNNNNNCNNNCCNNNCCCNNNNCNN
CNNNNNNN

Endophyte: 154
TACGGNGCAGNGNNTCGCGGATTATTGGGCGTAAAGAGCTCGTANGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGT
GGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGT
TTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGG
GGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAG
AACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTGGNNAAAA
NGTTGG*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 155
CGCTCTGTCGTGANNGTTGCNTCTTNTCTGGACATGTNGAGCTCGTAGGCGGTTTGTCGCGTCGGCCGTGAAATCTCCA
CGCTTAACGTGGAGCGTGCGGTCGATACGGGCAGACTTGAGTTCGGTAGGGGAGACTGGAATTCCTGGTGTAGCGGTG
AAATGCGCAGATATCAGGAGGAACACCGGTGGCGAAGGCGGGTCTCTGGGCCGATACTGACGCTGAGGAGCGAAAGC
GTGGGGAGCGAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGTTGGGCGCTAGGTGTGGGCGACATCCACGT
TGTCCGTGCCGTAGCTAACGCATTAAGCGCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGGCCCGCACAAGCGGCGGAGCATGTGGATTAATTCGATGCAACGCGAAGAACCTTACCTGGGCTTGACATGCGCCA
GACATCCCCAGAGATGGGGCTTCCCTTGTGGTTGGTGTACAGGTGGTGCATGGCTGTCGTCAGCTCGTGTCGTG*******NGA
ATGTTGNCNNNNCTCNNNTNCNNNNTNATTNCCNCCCTNTNTCCCNCACANTCACCNNNAGANNNNAATCANANNTNT
NANCNCTNTANNNCANNNTNTCANTTNTTGGTNNCATCCCTCTTNNCTTATCCTCNCCTNGCTAATCCNANATNNGNNN
NTNTAGNNCCNTATATNANANANNNNNNNNANCNTNCNNNTNTTACNAACATNTTACATCCATNANCNNNGCTTNNNNT
NCNACNTTAANTTTANGCGCCNCNNATNNCNCNNATTATTATNATC

Endophyte: 157
CTCTGTCTGAGNGTTGANN*******CATTTTGGGCGTAAANAGCTCGTATGCGGATNGTNGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGG
ATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTC*******NTCAGCTCGTGTCNTGA
NAATGTTTGNCCCCNNCTCNNTATNCTNTTCCCNNCACAAACCTCCNANANCANNATATNNCNNCCNACNACNNNNNC
TTCGNCCANNNCNACATTTCACNNCNTNNATCNCCCTCCCNCNCNCGNACCNCCNTCNNNNNCCNNNNTCNCCTNTCN
NCNANTNTNCTNNATCNNTTNNNNCNTTACNNAAACNNGACNNTCNTANACGATNNANCANANNNTNTTNNACCNNN
CCNNNNTCCCNTNTNCTCNTNTATNNNNTANNNATNTT

Endophyte: 158
CCTCGGTNCNGAGGN*******GTTGCGGTATTATTGGGCGTAAAGGAGCTCGTANGCGGTTTGTCGCGTCTGCTGTGAAATCC
CGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCG
GTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCNGCAAGGCTAAAACTCAAAGGAAT
TGACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATA
TACGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGT
GAAATGTTGG*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNCCCTNNNCNNNNNNNNNNNNCTNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNTTTNNNNNNNNNNNNNNCNNNNNNNNNANNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNTNTNNANNNNANANNNNNNNNNNNNNNNNNTNNTNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNCNNNNNNNTNTN
NNNNNCCNCNCNNNNNNNNNNNNNNNNNN

Endophyte: 159
CGCTCNGTCGTGAGAGTTGCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGG
ATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGAAAN
TGTTG*******NNNNNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNNNNNNANNCNNNNNNNNNNNNCNN
NTANNNNNNCNNNNNNNCNCNNCNNNNNANNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNCNNNTNNANNCNC
CCCCNNCNNNGCCCTNNNNNNCNN

Endophyte: 160
GTCGGTTCNGAGNTTTNGNGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGG
TTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGAAAA*
**NTNTTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNCNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNNNNANCNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNN

Endophyte: 161
CGCTCTGTCGTGAGNTGTTGANNNTTTTGGGNANANN***GACTCGTAGGCGGNTTGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACG
GATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACG
AGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAG
AATGTTGA***NNNNNCNCCCCNNNNTNTTCTTNNNTNNCNTNNNNTTNNANTCNNNCNCCCCCTNTCTNNNNCTCCNT
NTTTNCNCNNNCNATTCNNNTNNNTCNNNANNNCNNCNNNNNCNTCNNNTNNCNNNANTNNNNCNNCNNCCCNNNNN
NCNCCNCCNCCNTTATNTNTTNNCCNNNCTTATNNCNNNCNNNNCTCTNNNTANTANATNCNCACNNCCTNANNNCNN
TCNCNTCNNNTCANTNCNCCCANAA

Endophyte: 162
CGCTCTGTCGTGANANGTTGACTNATTNTNGGGNGN***AAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCC
CGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCG
GTGGAATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGA
AAGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTC
CACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAAT
TGACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATA
TACGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGT
GAG***NATGTTGNNNNNNNNNNNNNNACCCCCNCCNTNNANNNNCCNANCTNNNNCNANTNNNTNCANCNNATNCNTN
NNTNNNTGNTCCNTTTNTGTTATNANCNTNATNNNTNNCCCTNTNCCNNCNNTTCNCNNCGNNNCTTNNNNNTTNCCCN
ATNANNCCTTCCNNTNTACCNCTCCNNATNTTANTNTNNNATNNACTATANCNCNTCNNTCNCNCCCCTCNTTTTNNAN
TNTCCCCACCTTCCNNCCTNCNCNNNCNT

Endophyte: 163
CGCTCNGTCGTGATAGTTGCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAAACCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGAATGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGTTCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGC
GTGGGGAGCGAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGTTGGGCGCTAGATGTGGGGACCATTCCACG
GTTTCCGTGTCGCAGCTAACGCATTAAGCGCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGGCCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACG
AGAACGCTCTAGAAATAGAGAACTCTTTGGACACTCGTATACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGNAA
ATGTTG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNTNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNANCNNNNNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNCTN
NNNCCNNNNNNNNNNNNN

Endophyte: 164
GCTCTGTCGTGAGANGTTGACTCATNNTCGGGCGN***AANAANCTCGTACGCGGNTTGTNGCGTCTGCTGTGAAATCC
CGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCG
GTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCC
ACGGATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATAT
ACGACAACGGGCCATAAATGGTCAAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCCTCGTGTC*
**NNGAAATGTTGNCCNTCCCTATCCNCCNCTNTCCCNCCNNTNNATTANNCNCTCACNNNCNACNCANGNCGCTNATG
NANTNNACANANCCCNACNTCCNACATCNATTTCTNCNNCATNNCNTCNNTNCNTNNTCTTNCGCNCNCGTATNNATCT
NCCNACNAAACTTTCNNTNNCCATCCNCNNCCTCGNATACATNNCNCNCTGCNCNCCTCNCCCCCCCCNCTCCCCACTC
NANCGTANTGTCTACNNGCCNCNNNCACNANGCCANGNCCCCCTNNNTCACTNNTCTTNNT

Endophyte: 165
AGGGCGCAGCGTTATCCGGAATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAAACCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGG
ATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTGG*******NNA
ANNANTTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 166
CGCTCTGTCGTGANNAGTTGACTCNTGTCGTGANNGTTGNCTCGTNTGCGGATTGTTGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCCGATNGGCCNGAAAGGGCAAGNATCCTNCTGGGCCCGTAAACTTGAACCGC
CTTGAAGGGANCCCAAAAAGGGGTTNGGGGGGAAGCCAAACCAGGGCTAAATACCCTGGTGTCCACCCCGTAACGTTG
GAACTANTNNGGGGACCATTTCCACNGTTTTCGGNGANCCCANNCTAACCNANTTAAGTTTCCCCCCCCTTGGGGGGAA
TTCCNGGGCCCCCAANGGNTTANAAANCTTTNAAAAGGGAANNTTTNNNNNGGGGGACCCCNGNANNAAACCCCNCN
NNNNNCTCTNCCCGGTTTNNNTTTNNTTTTNNCCNNCNNNAAAAAACCNNTTTTCCCNNNNGNNTTTTCCCTNTTNCCN
CCC*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNANNNAGANTGNTNGTTNCTNNNNTCNGGNNNNNNAACTAGGANAG
GNNNNAATNGGNNNTNNGGNNGNGGNGNNNNNNNAANAGGNNTNNNNNNNNNNNCTNTCTCNCAATANTTTTNNNNN
NANTNNTNCCTCTCTNNNNNNNNNNNGGNNNNNGNNNNNNGGNGCNNNNNNNNNNNNNNATAAATTNNTGGGGGNNNN
NANANATNNCCNNNNNCNNNNNNNNNNGNNNNNNANANNNNNNNNCNNNNNNNNNCTGNNNNGNNTTGCGNTGG

Endophyte: 167
GTAAGNCACAGTNGTNATTCCGGCN*******TTATTGNCCGGTAAAGNGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATC
CCGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGC
GGTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGA
AAGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTC
CACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAAT
TGACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATA
TACGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGT
GAGATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGG
ATACTGCCGGGGTCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATG
CTACAATGGCCGGGTCAAAGGGCTGCAATACCCGTGAGGGGNAGCGAATCCCAAAAAACCNGTCCCAGTTCGGATTNG
AGGTCTGCAACTT

Endophyte: 168
GGNGGTGCAGGCGTTTCCGGCTTTATTGGGTTTAAAGGGTCCGTAGGCGGATCTGTAAGTCAGTGGTGAAATCTCACAG
CTTAACTGTGAAACTGCCATTGATACTGCAGGTCTTGAGTAAGGTAGAAGTAGCTGGAATAAGTAGTGTAGCGGTGAA
ATGCATAGATATTACTTAGAACACCAATTGCGAAGGCAGGTTACTATGTCTTAACTGACGCTGATGGACGAAAGCGTG
GGGAGCGAACAGGATTAGATACCCTGGTAGTCCATGCCGTAAACGATGCTAACTCGTTTTTGGGTTTTCGGATTCAGAG
ACTAAGCGAAAGTGATAAGTTAGCCACCTGGGGAGTACGTTCGCAAGAATGAAACTCAAAGGAATTGACGGGGGCCC
GCACAAGCGGTGGATTATGTGGTTTAATTCGATGATACGCGAGGAACCTTACCAAGGCTTAAATGGGAATTGATCGGTT
TAGAAATAGACCTTCCTTCGGGCAATTTTCAAGGTGCTGCATGGTTGTCGTCAGCTCGTGCCGTGAGGTGTTAGGTTAA
GTCCTGCAACGAGCGCAACCCCTGTCACTAGTTGCCATCATTCAGTTGGGGACTCTAGTGAGACTGCCTACGCAAGTAG
AGAGGAAGGTGGGGATGACGTCAAATCATCACGGCCCTTACGCCTTGGGCCACACACGTAATACAATGGCCGGTACAG
AGGGCAGCTACACAGCGATGTGATGCAAATCTCGAAAGCCGGTCTCAGTTCGGATTGGAGTCTGCAACTCGACTCTATG
AAGCT

Endophyte: 169
CTCGGTNCNGAGNGTTGCGGCATTATTGGGCGTAAAGGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGG
TTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAAA
ATGTTGG*******NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 170
CTAGCTCNTGTCGTGANACGTTGTTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTCGGGTCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGG
AATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTTACTGACGCTGAGGAGCGAAAGGG
TGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGG
ATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGA
GAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCTANAAA
AANGGTTGG***NNNNNNNNNNNNNNCNNNNNNNNNNNNNNCNNNNNNCNNNNNNNNNNNNNNNNNNCNNNNNTTNTT
NCTNCNTNTNNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNANNNCTTNNNNANNNNNNNNNNTTNNCNNCNC
NNNCNTANNNCNNNNCTNNNNNNNTNNNNNANNNNANNCTNNNNNNNCNCCCTNTNNNNNTCCNCCNTNNNTNNTNN
NTNNNNNNNNNNNCNTTCNNNNNNC

Endophyte: 171
CGCTCTGTCGTGAGANGTTGACTNTTNTNGGGNNNNN***AGAGCTCGTANGCGGTTTGTCGCGTCTGCTGTGAAAACT
GGAGGCTCAACCTCCAGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCG
GTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATAT
ACGGGAACGCTGCAGAAATGTAGAACTCTTTGGACACTCGTATACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTG
***NGNANGTTGNNNCNCTTTNTCNCNNNNNGCCTTTTANNNCTCANNNTTTTTCCNNNNNTNNCCTCCNCNNANNNNT
ACNNATCNNNTNNCCNCTCTNTNATNNTTNTTTNCANNNANNCCCNNTNANTTNNACNNCCCCCNNCNCCNTTNTTNCC
CTNTNTTTCTTNTNNNNTCNTAAANNTCANCNCCNNNNNTNAACNNTCCCNNNNTNTATNTNCTNNNNCCANCNTNCAT
CNNNTNNNNT

Endophyte: 172
AAGGTGCAAGNGNTCTCGGATTACTGGGCGTAAAGCGTGCGTAGGTGGTGGTTTAAGTCTGTTGTGAAAGCCCTGGGC
TCAACCTGGGAATTGCAGTGGATACTGGATCACTAGAGTGTGGTAGAGGGTGGCGGAATTCCCGGTGTAGCAGTGAAA
TGCGTAGAGATCGGGAGGAACATCCGTGGCGAAGGCGGCCACCTGGGCCAACACTGACACTGAGGCACGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTTCAACTTGGAACC
CAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGG
GCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATCCACGGAACT
TTCCAGAGATGGATTGGTGCCTTCGGGAACCGTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTG***NGNNAAAAA
ATNTNGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 173
CTCGGTNNN***GAGNGTTGCGGCATTATTGGGCGTAAAGAGCTCGTNTGCGGNTTGTCGNGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCTTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
CATGGGGAGCGAACAGGATTAGATACCCTGGTAGTCCATGCCGTAAACGTTGGGCGCTAGATGTAGGGACCTTTCCAC
GGTTTCTGTGTCGTAGCTAACGCATTAAGCGCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGGCCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATACAC
CGGAAACGGCCAGAGATGGTCGCCCCCTTGTGGTCGGTGTACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGG***N
NAAATGTTGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 174
NTCGGTNCNGAGNNN***TGCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACG
GTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACG
AGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGNAA
ATGTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNN

Endophyte: 175
TAGGGTCCGAGCGTTGTCCGGATTACTGGGCGTAAAGAGCTCGTAGGTGGTTTGTCGCGTTGTTCGTGAAAACTCACAG
CTTAACTGTGGGCGTGCGGGCGATACGGGCAGACTGGAGTACTGCAGGGGAGACTGGAATTCCTGGTGTAGCCGGTGG
AATGCGCAGATATCAGGAGGAACACCGGTGGCGAAGGCGGGTCTCTGGGCAGTAACTGACGCTGAGGAGCGAAAGCN
GTGGGGAGCGAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGGTGGGTACTAGGTGTGGGTTTCCTTCCTTGG
GATCCGTGCCGTAGCTAACGCATTAAGTACCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGGCCCGCACAAGCGGCGGAGCATGTGGATTAATTCNATGCAACGCGAAGAACCTTACCTGGGTTTGACATGCACAG
GACGCCGGCAGAGATGTCGGTTCCCTTGTGGCCTGTGTGCANGTGGTGCATGGCTGTCGTCACTCTG***NNNGAAAAA
NNNNNNNGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNAGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NTNNNNNNNTNNNNNNNNNNNNNNNNNNNNN

Endophyte: 176
TACGGNCCAGNGNTATGCGGATTATTGGGCGTAAAGAGCTCGTANGCGGTTNGTCGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGT
GGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGGA
TTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGG
GGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAG
AACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTG***NGNNGAN
NNNGTTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNN

Endophyte: 177
NTCGGNGCAGNGNN***ATCGCGGATTATTGGGCGTAAAGAGCTCGTNTGCGGNTNGNCGNGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCAC
GGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
GAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGG***
NAAAATGTTGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 178
CTACGGTCCTNACATGTTGCGGCATTACTGGGCGTAAAGAGCTCGTAGGTGGTTTGTCGCGTTGTTCGTGAAAACTCAC
AGCTTAACTGTGGGCGTGCGGGCGATACGGGCAGACTAGAGTACTGCAGGGGAGACTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCGGTGGCGAAGGCGGGTCTCTGGGCAGTAACTGACGCTGAGGAGCGAAAGC
GTGGGGAGCGAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGGTGGGTACTAGGTGTGGGTTTCCTTCCTTGG
GATCCGTGCCGTAGCTAACGCATTAAGTACCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACG
GGGGCCCGCACAAGCGGCGGAGCATGTGGATTAATTCGATGCAACGCGAAGAACCTTACCTGGGTTTGACATGCACAG
GACGCTGGTAGAGATATCAGTTCCCTTGTGGCCTGTGTGCAGGAGGTGCATGGCTGTCGTCAGCTCGTGTG***NANNA
AANNNTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 179
CTCTGTCTGAGANTTGCGGATTATTGGGCGTAAAGGACTCGTGTGNNGATANGTTGGTCTGCTGTGAAATCCCGAGGCT
CAACCTCGGGCCTGCAGTGGGTACGGGCAGACTANAGTGCNGTANGGGAGAATTTGGNAATTCNNNNNNNNNNNNNN
AGNNAANCTGAAGGATTCNAGAANGANCNNGGGAAGCCATCTCTNNCCNNANTNACCTNNGGACNAAAGGNGGGNAC
CNACCNGCTTNGATCCCCTGGTNTTCNCCCCGTAACTTGGAANTNAATNNGGGGTCNTTCCCCGGTNTCGGGAANCNTN
AANCTTTAGNTTTCCCCCNNGGGATCNGCCCAAGGTTTACTTCNAANGNNTTNNCGGNGCCCCACCCTACNGCGGACN
NTNCTNNTTANNTTTTNTTNNTNCCAAAACCTTNCCNNGNNTTNCNNTTNTCNAAAANNNCCNAAACTNNTGCCCNCNN
TTTCNNNCNNANCAANANAGGGNCGNNNNNCTTNTCTCCANNTTCNCNTCNCNACAAACNTNTCCCNCCCCTCCCNNC
TCNNAAAATATNACNNTNNNNNCNCCCCTCCCCCNCAACCNNNNANCTATTNCTTACNTNTNCCCCTNCCTTCCNTTTN
TTT

Endophyte: 180
GGCGCAAGCGTTATCCGGAATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCT
CAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAAT
GCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTGG
GGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTC
CGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAAC
GGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGATGTTG
GGTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACTGCCGGG
GTCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACAATGGCC
GGTACAAAGGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGANGTCTGCAACT

Endophyte: 181
TATGGCGNAGCGATTATTCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGT
GGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGGA
TTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGG
GGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAG
AACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTGGNAAAAN
ANNTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 182
CTCGTGTCGTGAGGAGTTGNGNNATNNNTGGGCGTAAAGGGCTGCGTAGGCGGACTCTTAAGTCGGGGGTGAAAGCCC
ANGGCTCAACCCTGGAATTGCCTTCGATACTGANAGTCTTGAGTTCGGAAGAGGTTGGTGGAACTGCNAGTGTAGAGG
TGAAATTCGTAGATATTCGCAAGAACACCAGTGGCGAAGGCGGCCAACTGGTCCGATACTGACGCTGAGGCGCGAAAG
CGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGCCAGCCGTTGGGGTGCATGCAC
TTCAGTGGCGCAGCTAACGCTTTAAGCATTCCGCCTGGGGAGTACGGNCGCNAGATTAAAACTCAAAGGAATTGACGG
GGGCCCNCACAANCGGTGGAGCATGTGGTTTAATTCTAAGCAACGCGCAGAACCTTACCANCTTTTGACATGTNCGGTT
TGATCGACAGAGATGTCTTTCTTNANTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGANA
AANGNTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 183
CGCTCTTGTCGTGANNNGTTGACTCATTGTNGNGNANNNNGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCNGCCAGATATCANGGCAGGAACCACCCGAATGGCCGAAGGCAGATCTCTGGGCCGTACTGACGCTGAGG
AGCGAAAGGGTGGGGAGCAAACAGGCTTAAATCCCTGGTAGTCCACCCGTAAACCGTTGGGAACTATTTGTGGGGGTC
CATTTCCCACCGGATTTCCNTNGGACNNCANCTTAACNNCAATTAANANTNCCCCCNTCNNCTTGGGGNGNANTNNCN
NGGCNCCNNTANGGGNNTTNAAAATTNAAATGGNNTTTTTCCCGGGNGNCCCCCCTNNNNNCTCNCNNGNCCCCCCCC
CCNNCCTTNNNNANTNANGANCTANCCNCNNNCNTAACCCTTANNGNNCANGNTTNGNTAGAGNAANCNNAAACCGN
NCCCCGTANANATGNCGTCCNCCTCNNGNGGAACCNNGTCTTAANCCAAGNGNNNCNCTAANNNTCCCNCCCANANTC
AANTNTCTNACATACNTNTTCNCNCNCTNCCNTCTCCCCNCCCGNCCCNNTNTNCNTCNNCCATNCNCCTNNCNTCATC
GGGNCCNGNCCACATCNTATCATNCNNTCNATANNCNTCCTCTCTNCNTNCTATCTNNCACTCTCCCTNTCNACNTACN
NTNNNCANCNNTNNNCNTNNCACATTATGACGTNNNCNNCTCCCNCGTCNACCNNNCTCGNNNGNATNNATNNTNGNC
NCNCGTCTCTTTNTCNTTCCCNNTCACNCATNATTTCGTNT***N

Endophyte: 184
CTCNGTCCNGAGTGTTGCGGATTTTGGGCGTAAAGAGCTCGTANGCGGTTNGTCGCGTCTGCTGTGAAATCCCGAGGCT
CAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAAT
GCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGGTGG
GGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTC
CGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAAC
GGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGA***NAATG
NTTGGNCCCNCCCNNNNTCCNNCNNANCTATNNTCCCNNCNNNNTNCACNCNNGCCCTNTNNCNNNNNNAANNACNC
NNCTCTNCNCTNNCCNCNNCNTNCNTCTTNCTNCNCTTCCCCTCCCNNTCNTCCTNCNNCNCCCTNTCNANNNNCNCCN
CNTNNTCNNNCANCANANNNCANTNNNNTCCNNCCCNCTCNNNNNCCNTNANNNTGTNCNNNNNNNCCNNACNCCNN
CNNCNCCNCNNNTNNCNCNACTNTTTTTN

Endophyte: 185
ANCTCGTGNTCNTGNAGTTNTTGGGNTN***ATTACTCGGGCAGTAAAGCGTGCGCAGGCGGTGATGTAAGACAGATGT
GAAATCCCCGGGCTCAACCTGGGAACTGCATTTGTGACTGCATCGCTGGAGTACGGCAGAGGGGGATGGAATTCCGCG
TGTAGCAGTGAAATGCGTAGATATGCGGAGGAACACCNGATGGCGAAGGCAATCCCCTGGGCCTGTACTGACGCTCAT
GCACGAAAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGTCAACTGGTTGTTGGGT
CTTCACTGACTCAGTAACGAAGCTAACGCGTGAAGTTGACCGCCTGGGGAGTACGGCCGCAAGGTTGAAACTCAAAGG
AATTGACGGGGACCCGCACAAGCGGTGGATGATGTGGTTTAATTCGATGCAACGCGAAAAACCTTACCCACCTTTGAC
ATGTACGGAATCCTTTAGAGATAGAGGAGTGCTCGAAANAAAACCGTAACACAGGTGCTGCATGGTTGTCNTCAGCTC
GTGTGGGAAAATCGTT***NANANNCNNAANNNNNNNNATTNTTNTTTNNNNTTTNATTNNNCATACANCTANNNTNACN
TNNATTNTAACTNCTAATCCNATTNTNNCANNCNNNNCNTCTTNNNNNNTNTNTTTCNNCTNNTNTTCCACNNGNTCCC
NNCNNNNNNCCANNNCTCCNNNACNCNCTNTCNTTNNCNNTTTNNTTTTNTTCNNNCCCNTNNTTNNNNTTCCCCCTAN
NNNNNTGCCTANNTCTCTTTTCCATCCNCNCTNT

Endophyte: 186
N***TACGGNGCAGNGTNTCGCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCA
CGGATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTG
ACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATA
CGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTGGAA
AA***NNTNTTGNCCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNCNNCCNNNNNNNNNNNNNNNNNNN
NNNNCNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNCNNNNCNNNNNNNNNNNNNNNCNNCNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNNTNNNN

Endophyte: 187
CCTCTGTCTGAAAGTTGGCTATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGC
TCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAA
TGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTG
GGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTT
CCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGG
ACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAA
CGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGT***NANATG
TTGNCNNNNNCNATNCTNNNNCTNTNNNTANNCACTCTATCCTNTNTNTNTANTCACTANNNNNNATCNNNATNTCNTA
AAATNNNTNATTTNACAANNCANGANNANAACNCTNACNTNNTNAAANNCCCTTNTNNNTNAANGNNCNTCNNANAA
NGNNATNNGNNCCCNNANTCNNNTNCCCTNGNNCNNACCAACNCNAANNGNTNNNNNNNCCNNCTNTANANTNNCTT
CCCCCNCTNTNNNNNTNNNNTTTNTNN

Endophyte: 188
CGTNGGTNCNGNGNTNTGCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAG
GCTCAACCTTGGGCCTGCANTGGGTACNGGCAGACTAGAGTGCGGTAGGGGANATTGGAATTCCTGGTGTAGCAGGTG
GAATGCGCAGATATCAGGAGGAACACCAGATGGCGAAGGCAGATCTCTGGGCCGNNACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGNGAACTAGTTGTGGGGACCATTCCAC
NGTTTCCGTGACGCANCTAACGCATTAANTTCCCCNCCTGGGGANTNCGGCCGCANGGCTAAAACTCAAAGGAATTGA
CGGNGACCCCCACAAGCGGNGGANCATGCGGATTAATTCGATGCAACNCGAANAACCTTACCAAGGCTTGACATATAC
NAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCNTAAACANGTGGTGCATGGNTGTCGNCANCTCGTGTNGGNA
AANATTTG***NNNNNNNNNNNCNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNNTNNNNNNNNNNNNNANNNNNNN
NNNNNNNNNNCNCNNNNNNNNNNNNNTNNNNNNANNNNNNNNTNNNNNNNNTNNNCCNNNNNNNGNNNNNNNNNN
NNNNCNNNNNTGNNNNNNNNNNNNNNNNNNNNNNNNNANNNNNNNNNNANNNNANNNNNNNNGNNNNCCNNNNCCNCN
NATNTNNNNN

Endophyte: 189
CTCNGTCTGAGAGTTGCGGATTATTGGGCGTAAAGAGCTCGTANGCGGTTNGTCGCGTCTGCTGTGAAATCCCGAGGCT
CAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAAT
GCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTGG
GGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGGATTC
CGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGA
CCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAAC
GGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGAGAAATGTT
GCC***NNCNNNNCCNCNNNNCNANCTNATNNNNNCTNNNCNCCNNNCNNNNNNNNTNTNNTNNNNCNNNCNCNNNN
NCTCNNCCNNTCNNNTNTNCNNCTANCNNNCNNNNCCCCNCCNNNNCNNTNNNCANCNCNCNCTNCCANTCCACCNNN
TNNNNTNNNNNTTNNNNCNNNNCNNNNNNCNTCNNNCNCNANNTTTNNTTTNANTNNANATCCNNNNNNNNTACCNN
CTNTNCNNNNNATNCNTCNNNTTN

Endophyte: 190
GTCNAACAAGGTAGCTCGTAAGCTTGGTTCCCGGGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCAC
GGATTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATACAC
GAGAACGCTGCAGAAATGTAGAACTCTTTGGACACTCGTGAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAG
ATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACT
GCCGGGGTCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACA
ATGGCCGGTACAAAGGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGAGGTCTG
CAACTCGACCTCATG

Endophyte: 191
CCTCGGTGCTNANNGTTGCGGATTACTGGGCGTAAAGAGTTCGTAGGCGGTTTGTCACGTCGTCTGTGAAAACCCACCG
CTCAACGGTGGGCCTGCAGGCGATACGGGCAGACTTGAGTACTGCAGGGGAGACTGGAATTCCTGGTGTAGCGGTGAA
ATGCGCAGATATCAGGAGGAACACCGGTGGCGAAGGCGGGTCTCTGGGCAGTAACTGACGCTGAGGAACGAAAGCGT
GGGTAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGGTGGGCGCTAGGTGTGGGTTCCTTCCACGGGA
TCTGTGCCGTAGCTAACGCATTAAGCGCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGG
GGCCCGCACAAGCGGCGGAGCATGTGGATTAATTCNATGCAACGCGAAGAANCCTTACCTGGGTTTGACATATACTGG
AAAGCTGCANAGATGTATCCCCCNTTGTNGNCCNCATACAGGTNGNGCATGGCNTGTTNNCACCTCTNGTNTGNNANT
NNTT***NNNNNNNCCTTTTGTCCNCNCNCCCNNCNTGCGCNCNGNTTNANNTAANNNTNTTTCCNNTNNCTNNNATNT
GNNCTNNCCANNTATNANCTNCNNNNTNNTCNAATCCTCCNTTNNCGNANACCCCNNANTNNCTTTCTTNNNNTNTCCG
NAAATNTAANNNNNNANNGNNNCACTNNNCNNTNNANACCNCNANNNGTTNTNTTNCCCCCCCTNANNCNCTANNTTT
TNTC

Endophyte: 192
CTCGTGTCGTGAGATGTTGCGNCATCACTGGGCGTAAAGGGCGCGTAGGCGGACTCTTAAGTCGGGGGTGAAAGCCCA
GGGCTCAACCCTGGAATTGCCTTCGATACTGAGAGTCTTGAGTTCGGAAGAGGTTGGTGGAACTGCGAGTGTAGAGGT
GAAATTCGTAGATATTCGCAAGAACACCAGTGGCGAAGGCGGCCAACTGGTCCGATACTGACGCTGAGGCGCGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGCCAGCCGTTGGGGTGCATGCACT
TCAGTGGCGCAGCTAACGCTTTAAGCATTCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGG
GGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCTTTTGACATGTCCGGTTT
GATCGACAGAGATGTCTTTCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGNGGAAAA
AAANNTNGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 193
CTCGTGTCTGAGNGTTGCGGCATCACTGGGCGTAAAGGGCGCGTAGGCGGACTCTTAAGTCGGGGGTGAAAGCCCAGG
GCTCAACCCTGGAATTGCCTTCGATACTGAGAGTCTTGAGTTCGGAAGAGGTTGGTGGAACTGCGAGTGTAGAGGTGA
AATTCGTAGATATTCGCAAGAACACCAGTGGCGAAGGCGGCCAACTGGTCCGATACTGACGCTGAGGCGCGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAATGCCAGCCGTTGGGGTGCATGCACTTC
AGTGGCGCAGCTAACGCTTTAAGCATTCCGCCTGGGGAGTACGGTCGCAAGATTAAAACTCAAAGGAATTGACGGGGG
CCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGCAGAACCTTACCAGCTTTTGACATGTCCGGTTTGA
TCGACAGAGATGTCTTTCTTCAGTTCGGCTGGCCGGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGGNAAAAA
NTTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNN

Endophyte: 196
CGCTCNGTCGTGAGANGTTGCNTNTTTNGGGAANNTN***GACTCGTANGCGGNTTGTCGCGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGGTTGGGAACTAGTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATAT
ACGAGAACGGGCCANAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCG**
*NGAAATNTTGNTTANATNTNNTNNTTCCCTTTNNNNGNNCNGNCNNCCNTATNNNNTTTNNTNNANNNCNNNNTATCC
CANTTCTAGNTTCNTTCNNANNTNTCCNTNNTTATTTTTCTTTTNTTNATTCNNCATTGTNNCTNCTTTTTCCNTNNNNNN
CCNTANNTNNATTTNCNCNCNNTTTATNNNTTTNATNNNCTATTNTTNNNCTCNANNANACNCCCNATNNTATNTANNA
TCACATCNATACNCCCGCCNAANANTNGC

Endophyte: 197
CGCTCNGTCGTGAAANGTTGNNTNTNTNGGGAANNTNGAGCTCGTANGCGGNTNGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCAC
GGTTTCCGTGACGCANCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGANCATGCGGATTNATTCNATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
CATAACGGGCCACAAATGGNCAACTCTTTGGACACTCGTCAACANGNGGTGCATGGNTGTCGNTCANCTNGTGNCNTN
AACATGTTNGACGCTNTCNACCNCNNNCCTTNCCCCTTTNC***NNNCGNNNNCCTCCNNNGNNANNNTATNCTTTNTA
ATAGCCTNCCGCNNTTAACCCNTTNTTNNNGATCNCGNNTNNNAATNCNNNTNNAGNCTNTTNNCNATANTTNNCCAN
ANTNCCCNCTANTNNANNCGTCTNTNTTNNNACCCCCCNATNANTTNATNNATTNNTNTTNTTTCNCCNCNTCNNTTAT
TGCANGCNNCTTNGNTNTANNCNCCCNNTANTCNCNNNANNNNATCAAT

Endophyte: 198
CGCTCNGTCGTGAGANGTTGCNTNTTNTNGGGNANNTN***GAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCA
CGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTG
ACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATA
CGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGT**
*NAANAATGNTTGTNCCCCCTTTTCCNCCCNCNTCCTTTNTTNNNCATATNATNNNCATTAACNNCTNNNNCTNNNNNT
CNNANTTATTNCNNTNTCNNTCANNTNCNNCCCCNNNCNNANNNTATTTCNTCTNTANCNCNNCNNANCCCCNTATNTN
CNTNNCNCTTNNNTTNCGCCNNNNTNTANNTTNTTNNNTTCCTTTATCNCTTNCCCNNNTTTTNCCNATCNTNTTNTTTC
TCCCCCCCCCTNGACNNCCTNATNNNNCTCNNCT

Endophyte: 199
CNNTCTGTCGTGAAANGTTGN***CTCGTGTCGNGAAANTTGACTCGTATGCGGATTGTCGCGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCAC
GGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCNATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
GANAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGCGGTGCATGGTTGTC***NTCAGCTCGTGTNGT
GAGCATGTTGCGTTNTNCTNCNTNNANNCANTNCATTNATNCACNCNGCNCTCNNTTNCNCNTTGTNNTNTNNCNCCCN
TNTTCCACNNATNCCCGNNTTNTCCCNNNNCCCCTNNNNNNCNCCTNNCNNCTNTTNTCTCNNCTCCNCCCCCTCCCCC
CTANATNTCGATCCTNGATATCNNCNNCNTTTACTANNANTTCTTTTTTNANNCCNATNNAATNNNCCTANNCTNNAAT
NGTTNCCCTCATCNCCCCNCNCNTTCNNTNT

Endophyte: 200
CTCGGTNCN***GAGNGNTGCGGTATTATTGGGCGTAAAGGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCA
CGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTG
ACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATA
CGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGN
AAATTGTTG***NNNNNNNNNNNNNNNNNGNNNNNNNNTNNNNNNNNANNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNCNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNA
NNNNNNCCNNNNNNNNNNNNNNTTNNANN

Endophyte: 201
CGCTCNGTCGTGAGNTGTTGCGGTATTATTGGGCGTAAAGNAGCTCGTANGCGGTTNGTNGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTNGGGCCTGCATTGGGTACTGGGCAGACTAGAGTGCGGGTAGGGGAGATTGGAATTCCTGGTGTAGC
GGTGGAATGCGCAGATATCAGGAGGAACACCAGATGGCGAAGGCAAATCTCTGGGCCGTNACTGACGCTGAGGAGCG
AAAGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATT
CCACNGTTTCCGTGACNCATCTAACGCATTAAGTTCCCCNCCTGGGGAGTACGGCCGCANGGCTAAAACTCAAAGGAA
TTGACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCNATGCAACGCGAANAACCTTACCAAGGCTTGACNT
ATACNANAACGGGCCAAAAATGGNCAACTNTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTC
GGAAAATGTTGNC***NNNNNNNNNNNTNANANNNNNTNNNTNNNNNNNNNNNNNNNNTCNNNNNCNNNNNNNNNNN
NNNNNNCNTTNNNNCNNTNNTNNTNNTNNCNNNNCNNNTNNNNNNNCCNNCNNNNNTNTNNNNNCNNCNTNNNCNTT
NNNCNNNNTNNNNNTNNNCNCNNNNNNNNNTNTNNNNNNNNNNNNNNNCNNNTNNNNNNCNCCNCNCNNTCCNNN
TNNCCNCNNNNCNCCNNNATNTNNCN

Endophyte: 202
CGCTCNGTCGTGAGAAGTTGNN***TCGTNTCGNGAANNTTGACTCGTANGCGGATTGTCGCGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCAC
GGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
GAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGA
GAATGTTGTT***NCCNANCNNCACNCCNNCNTTTCCCNCCCCCCNNTTNNNNNTCNTTTTNNNANNNNNCTNNNNCCC
NCNNNNNCCCTTTNTNNNCNNNNCCNNNTCTNNTNCATANNNCNCCNNNTCNNNNANNNCCCTTCCNTCNACNCNATC
TNTNNNTNTACTNNGNTNCCCCCCTTNTNANTNCNNCNTTTTTNNNNNNCNCACCCNNNNCTTNNNTNCNTNTNNATNT
TATNTCCCCCNACNTTNNCNCNANTCNTTNNTTT

Endophyte: 203
GTCNACAAGGTAGCCGTAAGCTTGGTTCCCGGGTAANGCAGCTCGTAGGCGGTTTGTCGCTGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCAC
GGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
GAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGA
GATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATAC
TGCCGGGGTCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTAC
AATGGCCGGTACAAAGGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGAGGTCT
GCAACT

Endophyte: 204
CGCTCNGTCGTGAGATGTTGCGTATTATTGGGCGTANAGGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCAC
GGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGA
CGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAC
GAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGA
AAATGTTG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNCNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 205
CGCTCNGTCGTGAGAGTTGCGGTATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACG
GTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACG
AGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGAAA
ATGTTGC***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNTNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTN
NN

Endophyte: 206
AGTCNAACAGGTAGCCGTAAGCTTGGTTCCCGGGTAAAGCAGCTCAAGGGCGGCTTGTCNTGTNTGCNGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGG
TGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCA
CGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTG
ACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATA
CGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGA
GATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATAC
TGCCGGGGTCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTAC
AATGGCCGGTACAAANGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGANGTCT
GCAACTCGAC

Endophyte: 207
CGCTCTTGTCGTGANNNGNTTGGACTCGTGTCGTGAAAGTTGNCTCGTNTGCGGATNGTNGCGTCTGCTGTGAAATCCC
GAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCCG
GTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCGNNATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACAT
ATACNAGAACGGGCCAAAANTGGTCAACTCTTTGGACACTTCGTAAACAGGTGGTGCATGGNTGTCANTNANCTCGTG
TCGTGANATNTTGNCCCNACCNNNCATCANGCNCNATCTNNGNANGNCCCTACNCAAANNCCCTNATCCNCNTNCTNT
ACACTTCNNCCNNGTTTCACNCNCNNNNCTCTCACNNCTTNCTNTNTCNNNNCCNCCCCNCCTCNANNTNNTTNTTCNC
TGTCCNNGTCCANNCANCNGNTATTTNTNTTANCGATTTTNCNTATTCCCTNACNTCTTANNCTGTACNNTANTNTTATT
ATNCNCCCANNNTNANCCCCNCNCNGNCNCAATACNCTTNTTTT

Endophyte: 208
TCNNTGCNGNNTNN***TGCGGATTATTGGGCGTAAAGGGCTCGCAGGCGGTTTCTTAAGTCTGATGTGAAAGCCCCCG
GCTCAACCGGGGAGGGTCATTGGAAACTGGGAAACTTGAGTGCAGAAGAGGAGAGTGGAATTCCACGTGTAGCGGTG
AAATGCGTAGAGATGTGGAGGAACACCAGTGGCGAAGGCGACTCTCTGGTCTGTAACTGACGCTGAGGAGCGAAAGC
GTGGGGAGCGAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAGTGCTAAGTGTTAGGGGGTTTCCGCC
CCTTAGTGCTGCAGCTAACGCATTAAGCACTCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACG
GGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGTCTTGACATCCTCTG
ACAACCCTAGAGATAGGGCTTTCCCTTCGGGGACAGAGTGACAGGTGGTGCATGGTTGTCGTCAGCTCGTGNNAAAAA
NTNTTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNTNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 209
TTGGGCGTAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCTCAACCTCGGGCCTGCAGTGGGTAC
GGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAATGCGCAGATATCAGGAGGAACACC
GATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGGTGGGGAGCAAACAGGCTTAGATACCC
TGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTCCGTGACGCAGCTAACGCATTAAG
TTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGACCCGCACAAGCGGCGGAGCATG
CGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAACGGGCCAGAAATGGTCAACTCTT
TGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGATGTTGGGTTAAGTCCCGCAACGAGCGC
AACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACTGCCGGGGTCAACTCGGAGGAAGGTGGG
GATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACAATGGCCGGTACAAAGGGCTGCAATACC
GTGAGGTGGAGCGAATTCCAAAAAGCCGGTCCCAGTTCGGATTGAGGTCTGCAACTCGACCTCATGAAG

Endophyte: 210
NNTCGGTNCNGAGNNTTGN***GTATTTTGGGCGTAAAGGAGCTCGTGTGCGGATAGNNNGGTCTGCTGTGAAATCCCG
AGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGT
GGAATGCGCAGATATCAGGAGGAACACCNGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAA
GGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCA
CGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTG
ACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATA
CGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGA
***NATGTTGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNTTNNNNNNNNNNNNNNNNNN
NNNCNNTNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNTNNNNNNNNNNNNNNNNNNNNNANNNCCNNN
NNNNNNNNNNCNNNNNNANNNNNNNNNNNNNNNNNNNCNNNNNNNNNNNTNNNCNNNNTNNNTNNNNCCCCNNN
NANNCNNNTTTNNNNN

Endophyte: 211
GGCGCAGCGTTATCCGGAATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGCTC
AACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAATG
CGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGGTGGG
GAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACGGTTTCC
GTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGAC
CCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACGAGAACG
GGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGATGTTGG
GTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACTGCCGGGG
TCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACAATGGCCG
GTACAAAGGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGAGG

Endophyte: 212
TANGTGGCAAGCGTTGTNCGGATTATTGGGCGTAAAGGGCTCGCAGGCGGTTTCTTAAGTCTGATGTGAAAGCCCCCGG
CTCAACCGGGGAGGGTCATTGGAAACTGGGAAACTTGAGTGCAGAAGAGGAGAGTGGAATTCCACGTGTAGCGGTGA
AATGCGTAGAGATGTGGAGGAACACCAGTGGCGAAGGCGACTCTCTGGTCTGTAACTGACGCTGAGGAGCGAAAGCGT
GGGGAGCGAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAGTGCTAAGTGTTAGGGGGTTTCCGCCCC
TTAGTGCTGCAGCTAACGCATTAAGCACTCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGG
GGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGTCTTGACATCCTCTGAC
AACCCTAGAGATAGGGCTTTCCCTTCGGGGACAGAGTGACAGGTGGTGCATGGTTGTCGTCAGCTCGTG***NGNAAAA
AANNTTTGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 213
GTCNNNACGTNGNCGTANGCTTGGCTGCNN***GGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCC
GGGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGT
GAAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCNGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAA
GCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGATGTCGATTTGGAGGTTGTGCCCTTGAG
GCGTGGCTTCCGGAGCTAACGCGTTAAATCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGAC
GGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATCCACA
GAACTTTCCAGAGATGGATTGGTGCCTTCGGGAACTGTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAA
ATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTATCCTTTGTTGCCAGCGGTTNGGCCGGGAACTCAAAGGAGACTG
CCAGTGATAAACTGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGACCAGGGCTACACACGTGCTACA
ATGGCATATACAAAGAGAAGCGACCTCGCGAGAGCAAGCGGACCTCATAAAGTATGTCGTAGTCCGGATTGGAGTCTG
CAACTC

Endophyte: 214
CGNTCNTGNTCNGGANNN***GTTTGGACTCGTTGTCGTGAAAGTTGAGCTCGTATGCGGATNGTNGCGTCTGCTGTGAA
ATCCCGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGT
AGCGGTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAG
CGAAAGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCA
TTCCACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGG
AATTGACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGAC
ATATACGAGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCCGTCANCTCGTG
TCGTGAGATGTTGCCCTC***NCTCNNNCTNNCNTTCTNCNCCTNCACCNCCNCNCTANNTNCTNNATNTNNNNACCCTC
NCTACNCCNCANNCNCNANNNCAGCATTCANNCTTCNTNCTTTTANCCCNCCCTCACAATTAACNNCNNNCACTTCCNT
CCCNACANNNTNGNNCNNNTGCTCNNNNNTNCNNCNTNCCTACNCCNNGTNGCCNNNCTATCNCCNNAATTCNCNTCC
CTNCCNNGNNTCTCNNCCNGTCTCCNCCNTCNNANTTT

Endophyte: 215
GGAGGGTGCAAGCGTTAATCGGAATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCC
GGGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGT
GAAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCNGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAA
GCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGATGTCGATTTGGAGGTTGTGCCCTTGAG
GCGTGGCTTCCGGAGCTAACGCGTTAAATCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGAC
GGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATCCACA
GAACTTTCCAGAGATGGATTGGTGCCTTCGGGAACTGTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTG***NGNA
AAAANTTTNNGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNAAGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 216
GAGGTGCAAGCGTTAATCGGATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGG
CTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAA
ATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCNGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGATGTCGATTTGGAGGTTGTGCCCTTGAGGCGT
GGCTTCCGGAGCTAACGCGTTAAATCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGG
GCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATCCACAGAACT
TTCCAGAGATGGATTGGTGCCTTCGGGAACTGTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAAATGTT
GGGTTAAGTCCCGCAACGAGCGCAACCCTTATCCTTTGTTGCCAGCGGTNNGGCCGGGAACTCAAAGGAGACTGCCAG
TGATAAACTGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGACCAGGGCTACACACGTGCTACAATGG
CATATACAAAGAGAAGCGACCTCGCGAGAGCAAGCGGACCTCATAAAGTATGTCGTANTCCNGATTGGAGTCTGCAAC
TCGACTNCATGAAGTCNGAATCGCTA

Endophyte: 217
GTACNAACAAGGTAGCCGTAAGCTTGGTATCCCGGGTAAAGCAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCC
CGAGGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCG
GTGGAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAA
AGGGTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCC
ACGGTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATT
GACGGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATAT
ACNACAACGGNCCAAAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCA***NCTCGTGTC
GTGAAGATGTTGGGTTAAGTCCNGCACCGAGCNCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTTGGGAACTTNTG
GGATACTGCCGGNGGTCAACCTCGGANGAAGGTGGGGATGACNTCAAATCATCATCCCCTTATGTCTTGGGCTTTACGC
ATGTTNNAATGGNCNGGTNCAAANGGCTGCATTANCGTGAGGNGGAGCNNAATTCCCAAAAAACCCGNTCCCCATTTC
CGGATTNNANGTCTNAANCTCCANCTNATN

Endophyte: 218
CTCGGTNNGAGNGTTGCGGATTATTGGGCGTAAAGAGCTCGTAGGCGGTTTGTNNNGTCTGCTGTGAAATCCCGAGGCT
CAACCTNGGGCCTGCANTGGGTACTGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAAT
GCGCAGATATCAGGAGGAACACCAGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGGGTG
GGGAGCAAACAGGNTTAGATACCCTGGTAGTCCACCCCGTAAACGNTGGGAACTAGTTGTGGGGACCATTCCACGGTT
TCCGTGACNCANCTAACGCATTAANTTCCCCGCCTGGGGAGTACGGCCGCANGGCTAAAACTCAAAGGAATTGACGGG
GACCCGCACAAGCGGNGGANCATGCGGATTAATTCNATGCAACGCNAANAACCTTACCAAGGCTTGACATATACNAGA
ACGGGCCANAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCTNNAAAAN
NTTTGG***NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 219
TANGTGGCAAGCGTTATCCGGATTATTGGGCGTAAAGCGCGCGCAGGCGGTTTCTTAAGTCTGATGTGAAAGCCCACG
GCTCAACCGTGGAGGGTCATTGGAAACTGGGGAACTTGAGTGCAGAAGAGAAAAGCGGAATTCCACGTGTAGCGGTG
AAATGCGTAGAGATGTGGAGGAACACCAGTGGCGAAGGCGGCTTTTTGGTCTGTAACTGACGCTGAGGCGCGAAAGCG
TGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGAGTGCTAAGTGTTAGAGGGTTTCCGCCC
TTTAGTGCTGCAGCTAACGCATTAAGCACTCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGG
GGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGTCTTGACATCCTCTGA
CAACTCTAGAGATAGAGCGTTCCCCTTCGGGGGACAGAGTGACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAG
ATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTGATCTTAGTTGCCAGCATTTAGTTGGGCACTCTAAGGTGACTGC
CGGTGACAAACCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGACCTGGGCTACACACGTGCTACAA
TGGATGGTACAAAGGGCTGCAAGACCGCGAGGTCAAGCCAATCCCATAAAACCATTCTCAGTTCGGATTGTAGGCTGC
AACTCGCCTACAT***N

Endophyte: 220
TCTCNGTCNTGAANNTTGGCTNTTATTGGGNNTAAAGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGA
ATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGANGANCGAAAGGGT
GGGGAGCAAACAGGCTTATATACCCTGGTAGTCCACCCCGTAAACCNCTGGGAACTAGTTGTGGGGACCATTCNACGG
TTTNCGTGACNCCNCTAACGCATTAAATTCCCCGCCTGGGGANTACNGTCGCTAGGNTNNAACTCAAANGAATTGACG
GGNNACCTNCCCANCCNGNNGTACNTGCNNTTTNAATTTCATGNNTCGCAANANAACCTTACCNATGNTTGATATATNT
CTANCAACGGGGCGNANNACNNGTNTTANNTTCTTTNNACACTTATNATNCNGNCCGNNAGNNATGTNTTCGCAATTN
NNCTCTTCNTNNACNTNAANTTTCNCTNNCNTACT***NTTTTTTNCNNCCCGTNTCNGCTTNNNCNNCCTNAATCATCN
GNNNNNNTANNGCTGCTCNNANATNTNCANNTTTTTTNCTATTTCTNNTCTACNNNCANNNTNNTNCNTGACCCNNCTN
NTCCCNTTCTGTCNNNTNNNTNCGCTNNTNTNCNATTTTNTATNTCNCCNATANNANNTTTNNNTTNATAANGTATANT
NTNATAANNNANATTANANNNANTATTNTNTNACCCCCNNNNTANCCNNCATANTATNNNAT

Endophyte: 221
CGAGGGTGCAAGCGTTAATGCGGAATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCC
CGGGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGG
TGAAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCNGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAA
AGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGA
GGCGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGA
CGGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAG
AGAACTTNCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGNGAAA
AAA***NNNTNGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 222
NGAGGTGCAAGCGTTAATGCGGATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCG
GGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTG
AAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGC
GTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGGC
GTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGG
GGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAGA
ACTTNCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTGG*******NNA
AANAANNTGGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 223
NNAGGTGCAAGCNTTN*******ATGCGGAATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCC
CCGGGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCG
GTGAAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCNGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGA
AAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTG
AGGCGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTG
ACGGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTTACCTACTCTTGACATCCA
GAGAACTTNCCAGAGATGNNTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTTGAAA
AAAA*******NTTTNGGNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

Endophyte: 224
CTCNGTCTGACATNTTNGGAATTCTGGGCGTAAAGCGNCGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGGCTC
AACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAAATG
CGTANAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCCTGGACAAAANNCTTGCCNCTTCANGTTGCCAAANCG
TGGGAGCAAACAGATTAAATCCCCTGGNNNTCNCNCCNTAAACCAANTNTNNACCTTNGAAGGTTTGNCCCCCTTTNA
AGGGNNTTGGNCTTTCCCGGNAACNNTAA*******NCCCCCCCTTTTAAAANNNNNNCCCCCCCCCCTNNNNNNNNNNNNNN
NNNNNNNNNNAAAAAGGGNNNNAAAANNNNNAAAANNNNAATNTNGNCGGGGGGGGCCCCCCNNCAAAANNGNCG
NNNNNGCNCCCCCCCCGCGGNNNNNNNANNTNNNNNNNNNNNNNNNNNNNNNANNNGGGNNNNNNTNGANCGGGGGN
GGGGNNGGNNNNNNNNAATTNNNNNNNCGAGNNNNNNNTNNNNNNNNNNNNNNNNNNNNNCNNNNNNNNCNNNNNNNN
NNNNNNNTNNNNNNGNNCCNNNNNNNTNNNNGNANNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNGNCNTCNNCCNCNNNG

Endophyte: 225
CTCGGTNCNGAGTGNTGCGGTATTATTGGGCGTAAAGAGCTCGTGTGCGGATATGNTGGTCTGCTGTGAAATCCCGAGG
CTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCAGGTGG
AATGCGCAGATATCAGGAGGAACACCCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTANATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACG
GTTTCCGTGACGCAGCTAACGCATTAANTTCCCCGCCTGGGGAGTACGGCCGCAAGGCCTAAAACTCAAAGGAATTGA
CGGGGACCCCGCACAANCNGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATAT
ACNACAACGGGCCAGAAATGGTCAACTTNTTTGGACACTCGNTAACANGTGGNGCATGGTTGTCNTCANCTCGTGTCTT
AAAAANNTNTGTTNTNCTTNNCNCCNNCANCNCCCTTNCCCNNCCNCCNCCNCTNNCNGNNNTNTTNATTNNTTTNTNT
TCCCNCATTTTNCGATNTNTANNTNTNCCNCATTCNANATCNATNTTTNNCNTATTCCTNNCNTTCCNNCTCCCCNNCCA
CATAATTNTNNANCACTNANNGNCCGCNCNNTNNTCTTTNATNTCNTNNACTAGAATTCCCGTTAGCANCNNNTTCNNN
TATTTNTNTTCTANCGCCNGTTNNNTCGANNNATTTANGANT

Endophyte: 226
GTCNNCAGGTNGCCGTAGCTTGNCTNCCCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGGC
TCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAAA
TGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCGTG
GGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCTGTAAACGATGTCGATTTGGAGGTTGTGCCCTTGAGGCGTG
GCTTCCGGAGCTAACGCGTTAAATCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGG
CCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATCCACAGAACTT
TCCAGAGATGGATTGGTGCCTTCGGGAACTGTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAAATGTTG
GGTTAAGTCCCGCAACGAGCGCAACCCTTATCCTTTGTTGCCAGCGGTNNGGCCGGGAACTCAAAGGAGACTGCCAGT
GATAAACTGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGACCAGGGCTACACACGTGCTACAATGGC
ATATACAAAGAGAAGCGACCTCGCGAGAGCAAGCGGACCTCATAAAAGTATGTCGTAGTCCGGATTGGAGTCTGCAAC
TCGACT

Endophyte: 227
CGCTCTGTCGTGANANGTTGANTNTTATNGGGNGNNNNGAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGA
GGCTCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTNACTGACGCTGAGGAGCGAAAGG
GTGGGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGACCATTCCACG
GTTTCCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGAC
GGGGACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATACG
AGAACGGGCCAGAAATGGTCAACTCTTTGGACACTCGTAAACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAG
ATGTTG***NNNCNNNCCNCCCNTTCCTNNNNNNCCNTNCACNNTCNCCCCGNTNNCTTTCCCCTNCCNNCTCTNCNTCC
CCCCNNCNNANTTNCTCCNTTNTTNNCTNNCNACCCCNNCNNNCANNNNGCNCCNTTCCNCTNNTNCACTTNNNNTTCT
TTCNNNNTTCTNNNNNNCNNCCCCCCNANTNCTNATTATNNNNTNNNANTANCNNNCCCNNTTCNCANCNNCCATNNN
NTNTATTTNTNT

Endophyte: 228
CTCGGTGCNGAGNNNTGCGGNATTATTGGGCGTAAAGCAGCTCGTAGGCGGTTTGTNGNGTCTGCTGTGAAAACTGGA
GGCTCAACCTNCAACCTGCATTGGGTACTGGCANACTAGAGTGCGGTAGGGGANATTGGAATTCCTGGTGTAGCGGTG
GAATGCGCAGATATCAGGAGGAACACCAGATGGCGAAGGCAAATCTCTGGNCCGATACTGACGCTGAGGAGCGAAAG
GGTGGGGAGCAAACAGGNTTAGATACCCTGGTAGTCCACCCCGTAAACGNTGGGAACTAGTTGTGGGGACCATTCCAC
NGTTTCCGNGACNCATCTAACNCATTAANTTCCCCNTCTGGNGANNACNGCCGCANGGCTAANNCTCANANGAATTGA
CGGGGACCCNCACANGCGGNNGANCATGCGGATTAATTNNATGCNACGCNAAAAACCTTACCAAGGCTTGACATATAC
AANAACGCTGNAAAANTGTNGAACTCTTTGGACACTNGTATACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGGAA
AAAATNTTGG***NNNNNNNNTNNNNCNNNCNNNCCAATNCNCGGGGNCNNNNNNGCTNNTNNNNGNCNCTCNCNNTT
CNCCGNTNNNCNNTTNNTNTNNACCNNNNNNNNAANCNANNNNNANTNNTNCNNNNACNTCNNNNTTCCCCNANTNN
CNNNNNTNNTANGNNNCTNCNNNNCNCNNTCNNTNNNTCNNNGNANTNCNANNNNANNNNCNCNGNNNTAATNNNTN
NCTCCNATTACNCCNTNNTNNTTATT

Endophyte: 229
GGCGCAAGCGTTATCCGGAATTATTGGGCGTAAAGTAGCTCGTAGGCGGTTTGTCGCGTCTGCTGTGAAATCCCGAGGC
TCAACCTCGGGCCTGCAGTGGGTACGGGCAGACTAGAGTGCGGTAGGGGAGATTGGAATTCCTGGTGTAGCGGTGGAA
TGCGCAGATATCAGGAGGAACACCGATGGCGAAGGCAGATCTCTGGGCCGTAACTGACGCTGAGGAGCGAAAGGGTG
GGGAGCAAACAGGCTTAGATACCCTGGTAGTCCACCCCGTAAACGTTGGGAACTAGTTGTGGGGTCCATTCCACGGATT
CCGTGACGCAGCTAACGCATTAAGTTCCCCGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGG
ACCCGCACAAGCGGCGGAGCATGCGGATTAATTCGATGCAACGCGAAGAACCTTACCAAGGCTTGACATATAGAGGAA
ACGGCTGGAAACAGTCGCCCCGCAAGGTCTCTATACAGGTGGTGCATGGTTGTCGTCAGCTCGTGTCGTGAGATGTTGG
GTTAAGTCCCGCAACGAGCGCAACCCTCGTTCTATGTTGCCAGCACGTAATGGTGGGAACTCATGGGATACTGCCGGGG
TCAACTCGGAGGAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGTCTTGGGCTTCACGCATGCTACAATGGCCG
GTACAAAGGGCTGCAATACCGTGAGGTGGAGCGAATCCCAAAAAGCCGGTCCCAGTTCGGATTGAGGTCTGCAACTCG
ACCTCATGA

Endophyte: 477
GTCGATACGGTAGCCGTAAGCTTGGCTNCCGGTAAAGCGTGCGTAGGTGGTTGTTTAAGTCTGTTGTGAAAGCCCTGGG
CTCAACCTGGGAATTGCAGTGGATACTGGGCGACTAGAGTGTGGTAGAGGGTAGTGGAATTCCCGGTGTAGCAGTGAA
ATGCGTAGAGATCGGGAGGAACATCCATGGCGAAGGCAGCTACCTGGACCAACACTGACACTGAGGCACGAAAGCGT
GGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCCTAAACGATGCGAACTGGATGTTGGGTGCAATTTGGCAC
GCAGTATCGAAGCTAACGCGTTAAGTTCGCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGG
GGCCCGCACAAGCGGTGGAGTATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTGGTCTTGACATGTCGAGAA
CTTTCCAGAGATGGATTGGTGCCTTCGGGAACTCGAACACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATG
TTGGGTTAAGTCCCGCAACGAGCGCAACCCTTGTCCTTAGTTGCCAGCACGTAATGGTGGGAACTCTAAGGAGACCGCC
GGTGACAAACCGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGACCAGGGCTACACACGTACTACAAT
GGTAGGGACAGAGGGCTGCAAACCCGCGAGGGCAAGCCAATCCCAGAAACCCTATCTCAGTCCGGATTGGAGTCTGCA
ACTCGACTCCATGAAGTCG

Appendix 3. The 16S rDNA contig sequence length for 220 culturable endophytic bacteria isolated form surface sterilized crown tissue from Midlawn and Tifgreen cultivars of bermudagrass. Bold type indicates the high quality sequences, > 1.0 % N content and < 500 bases long. Recal=bacterium with recalcitrant cell walls. Control=bacterial colonies that grew on sterility control agar plates.

Endophyhte Identification Number	Primary Contig Sequence Length	Number of Ns	Percent Ns	Secondary Contig Sequence Length	Number Ns	Percent Ns
1	549	7	1.3	**538**	**4**	**0.7**
2	554	6	1.1	**550**	**4**	**0.7**
3	881	240	27			
4	781	133	17			
5	**790**	**4**	**0.5**			
6	811	27	3.3	**614**	**4**	**0.7**
7	**543**	**2**	**0.4**			
8	551	9	1.6			
9	557	6	1.1	**543**	**2**	**0.4**
10	**800**	**7**	**0.9**			
11	506	24	4.7			
12	**552**	**1**	**0.2**			
13	**551**	**2**	**0.4**			
14	780	11	1.4	**742**	**1**	**0.1**
15	525	20	3.8			
16	564	17	3			
17	554	6	1.1	**531**	**5**	**0.9**
18	**551**	**2**	**0.4**			
19	**553**	**3**	**0.5**			
20	**549**	**4**	**0.7**			
21	541	37	6.8			
22	550	6	1.1	**538**	**4**	**0.7**
23	**551**	**2**	**0.4**			
24	549	6	1.1	**538**	**3**	**0.6**
25	553	7	1.3	**527**	**3**	**0.6**
26	553	9	1.6	**521**	**3**	**0.6**
27	963	334	35			
28	554	11	2	**521**	**3**	**0.6**
29	560	19	3.4			
30	**556**	**1**	**0.2**			
31	552	18	3.3	474	1	0.2
32	**785**	**3**	**0.4**			
33	**784**	**7**	**0.9**			
34	**553**	**2**	**0.4**			
35	**787**	**1**	**0.1**			
36	**531**	**1**	**0.2**			

Endophyhte Identification Number	Primary Contig Sequence Length	Number of Ns	Percent Ns	Secondary Contig Sequence Length	Number Ns	Percent Ns
37	550	7	1.3	**522**	**4**	**0.8**
38	551	6	1.1	**539**	**4**	**0.7**
39	554	8	1.4	**533**	**3**	**0.6**
40	**551**	**2**	**0.4**			
41	**549**	**2**	**0.4**			
42	**551**	**4**	**0.7**			
43	559	13	2.3	**521**	**4**	**0.8**
44	553	11	2	**539**	**5**	**0.9**
45	551	6	1.1	**538**	**2**	**0.4**
46	**551**	**5**	**0.9**			
47	522	25	4.8			
48	**720**	**1**	**0.1**			
49	**522**	**0**	**0**			
50	**542**	**4**	**0.7**			
51	**551**	**1**	**0.2**			
52	**801**	**1**	**0.1**			
53	**545**	**0**	**0**			
54	558	65	12			
55	**536**	**0**	**0**			
56	885	240	27			
57	**550**	**2**	**0.4**			
58	**804**	**5**	**0.6**			
59	550	6	1.1	**534**	**0**	**0**
60	555	6	1.1	**548**	**3**	**0.5**
61	560	16	2.9	494	3	0.6
62	554	14	2.5			
63	**791**	**5**	**0.6**			
64	736	18	2.4	**642**	**5**	**0.9**
65	**555**	**3**	**0.5**			
66	559	8	1.4	**528**	**4**	**0.8**
67	551	7	1.3	**536**	**0**	**0**
68	**784**	**6**	**0.8**			
69	793	8	1	**773**	**0**	**0**
70	**554**	**5**	**0.9**			
71	852	149	17			
72	823	143	17			
73	542	9	1.7	**520**	**2**	**0.4**
74	795	113	14			
75	483	9	2	429	4	0.9
76	**790**	**2**	**0.2**			
77	**770**	**0**	**0**			
78	**551**	**4**	**0.7**			

Endophyhte Identification Number	Primary Contig Sequence Length	Number of Ns	Percent Ns	Secondary Contig Sequence Length	Number Ns	Percent Ns
79	555	7	1.3	**546**	**5**	**0.9**
80	554	7	1.3	**532**	**4**	**0.8**
81	**552**	**3**	**0.5**			
82	died					
83	died					
84	**547**	**4**	**0.7**			
85	**782**	**0**	**0**			
86	**771**	**5**	**0.6**			
87	**551**	**3**	**0.5**			
88	**551**	**3**	**0.5**			
89	553	9	1.6	**542**	**5**	**0.9**
90	549	9	1.6	**543**	**5**	**0.9**
91	**549**	**2**	**0.4**			
92	547	7	1.3	**524**	**1**	**0.2**
93	550	9	1.6	**516**	**3**	**0.6**
94	548	10	1.8	**505**	**3**	**0.6**
95	853	289	34			
96	**546**	**3**	**0.5**			
97	558	12	2.2			
98	890	178	2			
99	642	53	8.3			
100	**783**	**2**	**0.3**			
101	**550**	**3**	**0.5**			
102	**553**	**3**	**0.5**			
103	**549**	**3**	**0.5**			
104	791	35	4.4			
105	**793**	**0**	**0**			
106	549	10	1.8	**536**	**5**	**0.9**
107	802	113	1.4			
108	552	11	2	**522**	**5**	**0.9**
109	**785**	**7**	**0.9**			
110	**790**	**1**	**0.1**			
111	**554**	**5**	**0.9**			
112	558	6	1.1	**551**	**3**	**0.5**
113	521	11	2.1			
114	833	77	9.2			
115	**554**	**5**	**0.9**			
116	**552**	**4**	**0.7**			
117	865	163	18			
118	**796**	**0**	**0**			
119	830	171	21			
120	**544**	**5**	**0.9**			

Endophyhte Identification Number	Primary Contig Sequence Length	Number of Ns	Percent Ns	Secondary Contig Sequence Length	Number Ns	Percent Ns
121	**553**	**4**	**0.7**			
122	835	133	16			
123	**544**	**5**	**0.9**			
124	**554**	**3**	**0.5**			
125	646	134	21			
126	**553**	**3**	**0.5**			
127	**551**	**4**	**0.7**			
128	**552**	**3**	**0.5**			
129	**553**	**4**	**0.7**			
130	**553**	**5**	**0.9**			
131	548	6	1.1	**538**	**4**	**0.7**
132	880	222	25			
133	**804**	**6**	**0.7**			
134	549	7	1.3	**539**	**3**	**0.6**
135	recal					
136	**550**	**5**	**0.9**			
137	863	123	14			
138	**781**	**5**	**0.6**			
139	**551**	**5**	**0.9**			
140	**552**	**5**	**0.9**			
141	**552**	**4**	**0.7**			
142	**543**	**4**	**0.7**			
143	**547**	**1**	**0.2**			
144	**551**	**4**	**0.7**			
145	549	10	1.8	494	2	0.4
146	925	176	19			
147	876	245	27			
148	**555**	**4**	**0.7**			
149	796	14	1.8	**757**	**3**	**0.4**
150	832	214	26			
151	**554**	**5**	**0.9**			
152	807	34	4.2	**600**	**4**	**0.7**
153	**552**	**4**	**0.7**			
154	551	8	1.5	**537**	**4**	**0.7**
155	**542**	**5**	**0.9**			
156	died					
157	538	8	1.5	**506**	**4**	**0.8**
158	555	6	1	**540**	**3**	**0.6**
159	**551**	**2**	**0.4**			
160	**546**	**5**	**0.9**			
161	552	9	1.6	**515**	**1**	**0.2**
162	548	8	1.5	**512**	**1**	**0.2**

Endophyhte Identification Number	Primary Contig Sequence Length	Number of Ns	Percent Ns	Secondary Contig Sequence Length	Number Ns	Percent Ns
163	**553**	**3**	**0.5**			
164	543	8	1.5	**508**	**4**	**0.8**
165	**540**	**1**	**0.2**			
166	844	253	30			
167	793	9	1.1	**768**	**5**	**0.7**
168	**790**	**1**	**0.1**			
169	**553**	**3**	**0.5**			
170	**555**	**4**	**0.7**			
171	544	10	1.8	**507**	**1**	**0.2**
172	**535**	**2**	**0.4**			
173	550	9	1.6	**531**	**4**	**0.8**
174	549	6	1.1	**535**	**1**	**0.2**
175	**536**	**3**	**0.6**			
176	**536**	**5**	**0.9**			
177	550	10	1.8	**527**	**5**	**0.9**
178	**540**	**1**	**0.2**			
179	629	148	24			
180	**783**	**1**	**0.1**			
181	**540**	**1**	**0.2**			
182	546	17	3.1			
183	901	192	21			
184	**540**	**5**	**0.9**			
185	560	10	1.8	**532**	**3**	**0.6**
186	**544**	**4**	**0.7**			
187	**540**	**0**	**0**			
188	553	33	6			
189	**551**	**3**	**0.5**			
190	**798**	**1**	**0.1**			
191	491	6	1.2	477	3	0.6
192	**557**	**5**	**0.9**			
193	**554**	**3**	**0.5**			
194	Control					
195	Control					
196	542	11	2	**505**	**3**	**0.6**
197	560	29	5.2			
198	543	11	2	**505**	**1**	**0.2**
199	556	10	1.8	**506**	**4**	**0.8**
200	552	6	1.1	**543**	**4**	**0.7**
201	557	19	3.4			
202	554	8	1.4	**532**	**5**	**0.9**
203	**788**	**2**	**0.3**			
204	**544**	**3**	**0.5**			

Endophyhte Identification Number	Primary Contig Sequence Length	Number of Ns	Percent Ns	Secondary Contig Sequence Length	Number Ns	Percent Ns
205	**553**	**2**	**0.4**			
206	**792**	**6**	**0.8**			
207	528	12	2.3	468	4	0.9
208	550	11	2	**536**	**4**	**0.7**
209	**772**	**1**	**0.1**			
210	542	9	1.7	**525**	**4**	**0.8**
211	**773**	**1**	**0.1**			
212	**537**	**2**	**0.4**			
213	785	10	1.3	**755**	**2**	**0.3**
214	563	11	2	**545**	**4**	**0.7**
215	**539**	**1**	**0.2**			
216	**808**	**7**	**0.9**			
217	**535**	**3**	**0.7**			
218	552	26	4.7			
219	**794**	**1**	**0.1**			
220	844	140	17			
225	496	7	1.4			
226	**787**	**7**	**0.9**			
227	553	11	2	**514**	**1**	**0.2**
228	550	42	7.6			
399	752	124	17	475	25	5
477	**801**	**1**	**0.1**			

Appendix 4. The putative identification and BLAST information for the 169 culturable bacterial endophytes isolated from surface sterilized crown tissue from Midlawn and Tifgreen cultivars of bermudagrass. See Appendix 5 for NCBI Accession Number references.

Endophyte Identification Number	Putative Identification	BLAST E-Value	BLAST bits	BLAST Percent Identities	NCBI Accession Numbers
1	*Microbacterium*	0.0	989	510/515 (99 %)	AF474327
2	*Microbacterium*	0.0	1025	519/520 (99 %)	AF474327
5	*Acidovorax*	0.0	1483	755/758 (99 %)	AF137506
6	*Afipia*	0.0	1209	678/695 (97 %)	U87773
7	*Chryseobacterium*	0.0	900	510/525 (97 %)	AJ457206
9	*Acidovorax*	0.0	1015	533/536 (99 %)	AF137506
10	*Pantoea*	0.0	1530	775/776 (99 %)	AF364846
12	*Microbacterium*	0.0	1029	519/519 (100 %)	AF474327
13	*Acidovorax*	0.0	1031	536/539 (99 %)	AF137506
14	*Acidovorax*	0.0	1409	726/730 (99 %)	AF137506
17	*Microbacterium*	0.0	993	517/522 (99 %)	AF474327
18	*Acidovorax*	0.0	1041	539/541 (99 %)	AF137506
19	*Acidovorax*	0.0	1037	539/542 (99 %)	AF137506
20	*Enterobacter/Pantoea*	0.0	na	na	
22	*Enterobacter/Pantoea*	0.0	na	na	
23	*Microbacterium*	0.0	1027	518/518 (100 %)	AF474327
24	*Enterobacter/Pantoea*	0.0	na	na	
25	*Microbacterium*	0.0	999	513/517 (99 %)	AF474327
26	*Curtobacterium*	0.0	977	510/515 (99 %)	AB042096
28	*Curtobacterium*	0.0	985	512/518 (98 %)	AB042096
30	*Pseudomonas*	0.0	1055	538/540 (99 %)	AJ417070
32	*Pseudomonas*	0.0	1421	746/755 (98 %)	AF388027
33	*Pseudomonas*	0.0	1465	752/757 (99 %)	AF388027
34	*Pseudomonas*	0.0	1047	538/540 (99 %)	AJ417070
35	*Pseudomonas*	0.0	1528	779/782 (99 %)	AF388027
36	*Chryseobacterium*	0.0	916	511/525 (97 %)	AJ457206
37	*Enterobacter/Pantoea*	0.0	na	na	
38	*Stenotrophomonas*	0.0	1033	521/521 (100 %)	AY040357
39	*Stenotrophomonas*	0.0	1027	518/518 (100 %)	AY040357
40	*Stenotrophomonas*	0.0	1035	536/538 (99 %)	AY040357
41	*Stenotrophomonas*	0.0	1039	534/536 (99 %)	AY040357
42	*Stenotrophomonas*	0.0	1029	535/538 (99 %)	AY040357
43	*Microbacterium*	0.0	967	496/499 (99 %)	AF474327
44	*Enterobacter/Pantoea*	0.0	na	na	
45	*Microbacterium*	0.0	1025	517/517 (100 %)	AF474327
46	*Stenotrophomonas*	0.0	674	375/380 (98 %)	AY040357
48	*Pseudomonas*	0.0	1495	763/766 (99 %)	AF388027
49	*Stenotrophomonas*	0.0	1035	536/538 (99 %)	AY040357

Endophyte Identification Number	Putative Identification	BLAST E-Value	BLAST bits	BLAST Percent Identities	NCBI Accession Numbers
50	*Xanthomonadaceae*	e-170	603	361/375 (96 %)	AY040357
51	*Stenotrophomonas*	0.0	1068	539/539 (100 %)	AY040357
52	*Pseudomonas*	0.0	1556	793/796 (99 %)	AF388027
53	*Pseudomonas*	0.0	1033	538/541 (99 %)	AJ417070
55	*Xanthomonas*	0.0	989	527/535 (98 %)	AY135649
57	*Stenotrophomonas*	0.0	1035	536/538 (99 %)	AY040357
58	*Rhizobium*	0.0	1489	765/767 (99 %)	AF531767
59	*Stenotrophomonas*	0.0	1029	533/535 (99 %)	AY040357
60	*Pantoea*	0.0	1031	534/536 (99 %)	AF364846
63	*Enterobacter/Pantoea*	0.0	na	na	
64	*Afipia*	0.0	1160	666/685 (97 %)	U87773
65	*Curtobacterium*	0.0	987	517/521 (99 %)	AB042096
66	*Curtobacterium*	0.0	965	520/528 (98 %)	AB042096
67	Xanthomonadaceae	e-140	505	273/279 (97 %)	AY040357
68	*Enterobacter/Pantoea*	0.0	na	na	
69	*Brevundimonas*	0.0	1532	773/773 (100 %)	AJ227780
70	*Microbacterium*	0.0	1009	518/520 (99 %)	AF474327
73	*Microbacterium*	0.0	979	515/520 (99 %)	AF474327
76	*Microbacterium*	0.0	1528	787/790 (99 %)	AF474327
77	*Microbacterium*	0.0	1491	752/752 (100 %)	AF474327
78	*Microbacterium*	0.0	1001	514/516 (99 %)	AF474327
79	*Microbacterium*	0.0	959	510/520 (98 %)	AB042073
80	*Curtobacterium*	0.0	1007	519/524 (99 %)	AB042096
81	*Microbacterium*	0.0	1013	520/522 (99 %)	AF474327
84	*Afipia*	0.0	1019	521/522 (99 %)	AJ300771
85	*"Betaproteobacteria"*	0.0	1515	718/784 (99 %)	AF423075
86	*"Betaproteobacteria"*	0.0	1461	764/772 (98 %)	AF423075
87	*Staphylococcus*	0.0	1055	532/532 (100 %)	AF540985
88	*Staphylococcus*	0.0	1029	519/519 (100 %)	AF540985
89	*Microbacterium*	0.0	997	517/521 (99 %)	AY082800
90	*Brevundimonas*	0.0	1013	513/514 (99 %)	AJ227781
91	*Brevundimonas*	0.0	1029	526/527 (99 %)	AJ227781
92	*Rhizobium*	0.0	795	489/517 (94 %)	Z79620
93	*Microbacterium*	0.0	973	503/506 (99 %)	AF474327
94	*Microbacterium*	0.0	975	498/501 (99 %)	AF474327
96	*"Alphaproteobacteria"*	e-165	587	367/379 (96 %)	AF445712
100	*Microbacterium*	0.0	1398	745/752 (99 %)	AF474327
101	*"Alphaproteobacteria"*	0.0	922	523/537 (97 %)	AF445712
102	*Microbacterium*	0.0	1025	517/517 (100 %)	AY082800
103	*Brevundimonas*	0.0	1037	530/531 (99 %)	AJ227781
105	*"Betaproteobacteria"*	0.0	1540	790/793 (99 %)	AF423075
106	*Xanthomonas*	0.0	955	510/518 (98 %)	AY135649
108	*Microbacterium*	0.0	979	515/522 (98 %)	AY082800

Endophyte Identification Number	Putative Identification	BLAST E-Value	BLAST bits	BLAST Percent Identities	NCBI Accession Numbers
109	*"Betaproteobacteria"*	0.0	1467	752/755 (99 %)	AF423075
110	*Microbacterium*	0.0	1507	762/763 (99 %)	AF474327
111	*Brevundimonas*	0.0	1015	514/515 (99 %)	AJ227781
112	*"Alphaproteobacteria"*	0.0	902	527/545 (96 %)	AF445712
115	*Brevundimonas*	0.0	1021	515/515 (100 %)	AJ227781
116	*Curtobacterium*	0.0	1013	522/525 (99 %)	AB042096
118	*Acidovorax*	0.0	1552	790/791 (99 %)	AF137506
120	*Microbacterium*	0.0	983	511/516 (99 %)	AF474327
121	*Sphingomonas*	0.0	1001	513/516 (99 %)	AF131295
123	*"Alphaproteobacteria"*	0.0	1005	509/510 (99 %)	AF288308
124	*"Alphaproteobacteria"*	0.0	1015	512/512 (100 %)	AF288308
126	*Acidovorax*	0.0	1039	524/524 (100 %)	AF137506
127	*Acidovorax*	0.0	1025	517/517 (100 %)	AF137506
128	*Acidovorax*	0.0	1033	535/537 (99 %)	AF137506
129	*"Betaproteobacteria"*	0.0	1017	516/517 (99 %)	AF423075
130	*Acidovorax*	0.0	1033	523/524 (99 %)	AF137506
131	*Microbacterium*	0.0	1021	515/515 (100 %)	AF474327
133	*Klebsiella*	0.0	1517	768/770 (99 %)	AF511429
134	*Curtobacterium*	0.0	1027	518/518 (100 %)	AY273208
136	*Microbacterium*	0.0	991	513/516 (99 %)	Y17238
138	*Microbacterium*	0.0	1495	754/745 (100 %)	AF474327
139	*Microbacterium*	0.0	1029	519/519 (100 %)	AF474327
140	*Microbacterium*	0.0	1033	521/521 (100 %)	AF474327
141	*Microbacterium*	0.0	1023	518/519 (99 %)	AY082800
142	*Microbacterium*	0.0	981	513/519 (98 %)	AF474327
143	*Geodermatophilus*	0.0	912	523/540 (96 %)	L40620
144	*Microbacterium*	0.0	1033	521/521 (100 %)	AY082800
148	*Microbacterium*	4E-22	113	125/151 (82 %)	AB004725
149	*Microbacterium*	0.0	1471	746/748 (99 %)	AF474327
151	*Acitnobacteria*	0.0	924	507/521 (97 %)	AY048891
152	*Microbacterium*	0.0	1235	702/729 (96 %)	AF474327
153	*Amycolatopsis*	0.0	997	519/522 (99 %)	AY129777
154	*Microbacterium*	0.0	1019	516/517 (99 %)	AF474327
155	*Amycolatopsis*	0.0	999	504/504 (100 %)	AY129777
157	*Microbacterium*	0.0	967	511/519 (98 %)	AY082800
158	*Microbacterium*	0.0	1003	527/532 (99 %)	AF474327
159	*Microbacterium*	0.0	1029	519/519 (100 %)	AY082800
160	*Microbacterium*	0.0	1015	519/520 (99 %)	AF474327
161	*Microbacterium*	0.0	997	505/507 (99 %)	AY082800
162	*Microbacterium*	0.0	999	511/512 (99 %)	AF474327
163	*Microbacteriaceae*	0.0	971	515/522 (98 %)	AB028941
164	*Microbacterium*	0.0	928	488/494 (98 %)	AY082800
165	*Microbacterium*	0.0	1029	529/531 (99 %)	AY082800

Endophyte Identification Number	Putative Identification	BLAST E-Value	BLAST bits	BLAST Percent Identities	NCBI Accession Numbers
167	*Microbacterium*	0.0	1404	747/757 (98 %)	AF474327
168	*Chryseobacterium*	0.0	1443	774/788 (98 %)	AJ457206
169	*Microbacterium*	0.0	1021	522/532 (99 %)	AF474327
170	*Curtobacterium*	0.0	1017	516/517 (99 %)	AB042096
171	*Microbacterium*	0.0	959	501/507 (98 %)	AJ244679
172	*Xanthomonas*	0.0	967	509/516 (98 %)	AY135649
173	*Curtobacterium*	0.0	1001	514/518 (99 %)	AF474329
174	*Microbacterium*	0.0	1029	519/519 (100 %)	AF474327
175	*Mycobacterium*	0.0	995	527/532 (99 %)	AF480582
176	*Microbacterium*	0.0	1011	514/516 (99 %)	AY082800
177	*Microbacterium*	0.0	991	513/519 (98 %)	AF474327
178	*Mycobacterium*	0.0	1015	515/516 (99 %)	AF480593
180	*Microbacterium*	0.0	1546	782/783 (99 %)	AF474327
181	*Microbacterium*	0.0	1025	517/517 (100 %)	AY082800
184	*Microbacterium*	0.0	1003	512/515 (99 %)	AF474327
185	*Acidovorax*	0.0	963	503/508 (99 %)	AF137506
186	*Microbacterium*	0.0	1011	517/518 (99 %)	AY082800
187	*Microbacterium*	0.0	1031	520/520 (100 %)	AF474327
189	*Microbacterium*	0.0	1017	517/519 (99 %)	AY082800
190	*Microbacterium*	0.0	1499	762/746 (99 %)	Y17238
192	*"Alphaproteobacteria"*	0.0	1027	518/518 (100 %)	AF288308
193	*"Alphaproteobacteria"*	0.0	1029	519/519 (100 %)	AF288308
196	*Microbacterium*	0.0	948	498/503 (99 %)	AF474327
198	*Microbacterium*	0.0	995	504/505 (99 %)	AF474327
199	*Microbacterium*	0.0	872	425/428 (99 %)	AF474327
200	*Microbacterium*	0.0	1009	518/520 (99 %)	AF474327
202	*Microbacterium*	0.0	989	504/506 (99 %)	AF474327
203	*Microbacterium*	0.0	1469	748/749 (99 %)	AF474327
204	*Microbacterium*	0.0	1009	520/523 (99 %)	AF474327
205	*Microbacterium*	0.0	1023	518/519 (99 %)	AF474327
206	*Microbacterium*	0.0	1429	737/744 (99 %)	AF474327
208	*Bacillus*	0.0	1023	516/516 (100 %)	AY112667
209	*Microbacterium*	0.0	1503	770/773 (99 %)	AF474327
210	*Microbacterium*	0.0	955	491/493 (99 %)	AF474327
211	*Microbacterium*	0.0	1517	767/768 (99 %)	AF474327
212	*Bacillus*	0.0	1039	533/535 (99 %)	AY112667
213	*Klebsiella*	0.0	1473	752/754 (99 %)	AB074192
214	*Microbacterium*	0.0	965	508/515 (98 %)	AF474327
215	*Klebsiella*	0.0	1053	538/539 (99 %)	AB074192
216	*Klebsiella*	0.0	1532	799/807 (99 %)	AB074192
217	*Microbacterium*	0.0	1166	681/709 (96 %)	AF474327
219	*Bacillus*	0.0	1554	791/792 (99 %)	AY144451
226	*Klebsiella*	0.0	1477	756/759 (99 %)	AB074192

Endophyte Identification Number	Putative Identification	BLAST E-Value	BLAST bits	BLAST Percent Identities	NCBI Accession Numbers
227	*Microbacterium*	0.0	1031	513/514 (99 %)	AF474327
477	*Stenotrophomonas*	0.0	1526	770/770 (100 %)	AY040357

Appendix 5. National Center for Biotechnology Information (NCBI) accession numbers used in the putative identification of culturable bacterial endophytes isolated from the crown tissue of Midlawn and Tifgreen cultivars of bermudagrass and type species references.

NCBI Accession Number	Name	Reference
Culturable Bacterial Endophytes		
AY513502	*Escherichia coli* 0157 : H7	Gee et al. 2004
AY048891	Uncultured bacterium	Heuer et al. 2002
AF137506	*Acidovorax avenae* subsp. *citrulli*	Hu et al. 2001
U87773	*Afipia* genosp. 7	Whitney 1997
AJ300771	*Afipia* sp.	Mergaert et al. 2001
AF445712	Uncultured alpha proteobacterium	Bonheyo et al. 2001
AF288308	Uncultured alpha proteobacterium	La Scola et al. 2000
AY129777	*Amycolatopsis* sp.	Tan et al. 2002
AY144451	*Bacillus megaterium*	Xu et al. 2002
AY112667	*Bacillus pumilus*	Isenegger et al. 2003
AF423075	Beta proteobacterium	Pitulle et al. 2001
AJ227780	*Brevundimonas vesicularis*	Abraham et al. 1999
AJ227781	*Brevundimonas vesicularis*	Abraham et al. 1999
AJ457206	*Chryseobacterium* sp.	Kim and Lee 2002
AB042096	*Curtobacterium* sp.	Evtushenko et al. 2000
AY273208	*Curtobacterium flaccumfaciens* pv. *beticola*	Chen et al. 2003
AF474329	*Curtobacterium* sp.	Zinniel et al. 2002
AF395913	*Enterobacter aerogenes*	Yu et al. 2001
AJ002811	*Pantoea* sp.	Hoffmann et al. 1998
L40620	*Geodermatophilus obscurus obscurus*	Normand et al. 1996
AB074192	*Klebsiella* sp.	Fukuda et al. 2001
AF511429	*Klebsiella pneumoniae*	Ovesen et al. 2002
AB028941	*Microbacteraceae*	Suzuki et al. 1999
AF474327	*Microbacterium testaceum*	Zinniel et al. 2002
Y17238	*Microbacterium terrae*	Schumann et al. 1999
AB004725	*Microbacterium chocolatum*	Takeuchi and Hatano 1998
AB042073	*Microbacterium* sp.	Evtushenko et al. 2000
AY082800	*Microbacterium* sp.	Lau et al. 2002

NCBI Accession Number	Name	Reference
AJ244679	*Microbacterium* sp.	Fritz 1999
AF480582	*Mycobacterium lacticola*	Turenne et al. 2001
NCBI		
AF480593	*Mycobacterium neoaurum*	Turenne et al. 2001
AF364846	*Pantoea ananatis*	Coutinho et al. 2001
AJ417070	*Pseudomonas* sp.	Ramette et al. 2001
AF388027	*Pseudomonas* sp.	Macur et al. 2004
Z79620	*Rhizobium galegae*	Huber and Selenska-Pobell 1994
AY174112	*Agrobacterium* sp. (=*Rhizobium*)	Trott et al. 2003
AF131295	*Sphingomonas* sp.	Lee et al. 2001
AF540985	*Staphylococcus epidermidis*	Xu et al. 2002
AY040357	*Stenotrophomonas maltophilia*	Goris et al. 2001
AY135649	*Xanthomonas axonopodis* pv. *allii*	Roumagnac et al. 2004
Type Species		
AF420324	*Acidovorax facilis*	Swiderski 2001
AF338177	*Afipia felis*	van Berkum and Eardly 2002
X76958	*Amycolatopsis orientalis*	Warwick et al. 1993
X60646	*Bacillus subtilis*	Ash et al. 1991
M59064	*Pseudomonas diminuta*	Woese 1991
AY468449	*Chryseobacterium glem*	Matte-Tailliez et al. 2003
X77436	*Curtobacterium citreum*	Rainey et al. 1994
AJ251469	*Enterobacter cloacae*	Boye and Hansen 1999
X92356	*Geodermatophilus obscurus*	Eppard et al. 1996
AF130981	*Kelbsiella pneumoniae*	Drancourt et al. 2001
D21343	*Microbacterium lacticum*	Takeuchi and Yokota 1994
X55588	*Mycobacterium tuberculosis*	Wolters 1990
AF130953	*Enterobacter agglomerans*	Rojas et al. 1999
Z76672	*Pseudomonas aeruginosa*	Moore et al. 1996
AY509899	*Rhizobium leguminosarum*	Valverde et al. 2003
U37337	*Sphingomonas pauchimobilis*	Mueller et al. 1997
D83357	*Staphylococcus aureus*	Takahashi et al. 1996
M59158	*Xanthomonas* (=*Stenotrophomonas*) *maltophilia*	Woese 1990
X95917	*Xanthomonas campestris*	Moore et al. 1997

Appendix 6. Full taxonomic genera names of putatively identified culturable bacterial endophytes. Synonyms published prior to 1970 were not included. (NCBI Taxonomic List, 2004, J. P. Euzeby 2005 (www.bacterio.cict.fr)).

Acidovorax Willems et al. 1990 emend. Willems et al. 1992
    Equivalent name: *Acidivorax*
Afipia Brenner et al. 1992 emend. La Scola et al. 2002
Amycolatopsis Lechevalier et al. 1986
Bacillus Cohn 1872
Brevundimonas Segers et al. 1994 emend. Abraham et al. 1999
Chryseobacterium Vandamme et al. 1994
Curtobacterium Yamada and Komagata 1972
    Equivalent name: *Curtibacterium*
Enterobacter Hormaeche and Edwards 1960
Geodermatophilus Luedemann 1968
Klebsiella Trevisan 1885 emend. Drancourt et al. 2001
Microbacterium Orla-Jensen 1991 emend. Takeuchi and Hatano 1998
    Synonym: *Aureobacterium*
    Equivalent name: *Aureibacterium*
Mycobacterium Lehmann and Neumann 1896
Pantoea Gavini et al. 1989 emend. Mergaert et al. 1993
Pseudomonas Migula 1894
Rhizobium Frank 1889 emend. Young et al. 2001
    Synonym: *Rhizobacterium, Phytomyxa*
Sphingomonas Yabuuchi et al. 1990 emend. Busse et al. 2003
Staphylococcus Rosenbach 1884
    Synonym: *Aurococcus*
Stenotrohomonas Palleroni and Bradbury 1993
Xanthomonas Dowson 1939 emend. Vauterin et al. 1995
    Synonym: "*Phytomonas*"

Appendix 7. Indistinguishable and distinguishable 16S rDNA contig sequences of putatively identified *Microbacterium*. The bold numbers designate the randomly chosen set representative.

Indistinguishable

Set 1	**17**, 177
Set 2	202, **214**
Set 3	100, **160**, 162
Set 4	102, 141, **144**, 159, 161, 176, 181, 189
Set 5	2, 12, 23, 45, 70, 76, 77, 78, 81, 94, 110, 120, 131, 138, 139, 140, 149, 154, 167, 169, 174, 180, 184, 187, 198, **200**, 204, 205, 209, 211, 277

Distinguishable

Set A	1, 25, 43, 73, 79, 89, 93, 108, 136, 142, 148, 152, 157, 158, 164, 165, 171, 186, 190, 196, 199, 203, 206, 210, 217

Appendix 8. Bacterial endophytes documented in other studies and also documented in this study of the crown tissue of Midlawn and Tifgreen cultivars of bermudagrass.

Bacterial Endophyte	Plant	Organ	Reference
Acidovorax	Potato	Tuber	Sturz et al. 1999
	Clover	Roots	Sturz et al. 1998
	Potato	Tuber	Sturz et al. 1998
Afipia	Potato	Seedlings	Garbeva et al. 2001
Bacillus	Aspen	Wood	Knutson 1973
	Canola	Root	Germida et al. 1998
	Citrus	Branch	Araujo et al. 2002
	Citrus	Leaf	Araujo et al. 2001
	Clover	Root	Sturz et al. 1998
	Corn	Root	McInroy and Kloepper 1995a
	Corn	Kernel	Bacon and Hinton 2002
	Cotton	Plant tissues	Chen et al. 1995
	Live oak	Plant tissues	Brooks et al. 1994
	Sorghum	Stem	Zinniel et al. 2002
	Cotton	Seedlings	Zhao and Ma 1999
	Cotton	Root	Misaghi and Donndelinger 1990
	Elm	Stem, root	Mocali et al. 2003
	Grapevine	Xylem	Bell et al. 1995
	Maple	Stem	Hall et al. 1986
	Lemon	Root	Gardner et al. 1982
	Oilseed rape	Seedling	Graner et al. 2003
	Pea	Stem	Elvira-Recuenco & van Vuurde 2000
	Potato	Tuber	Lutman and Wheeler 1948
	Potato	Plant tissues	De Boer and Copeman 1974
	Potato	Tuber	Sturz et al. 1998
	Red Clover	Root, nodule	Sturz et al. 1997
	Rice	Plant tissues	Liu et al. 1999
	Sinapis		Pleban et al. 1997
	Sugar beet	Root	Jacobs et al. 1985
	Wheat	Leaf	Larran et al. 2002
	Wheat	Root	Germida and Siciliano 2001
	Vegetables	Plant tissues	Meneley and Stanghellini 1972
	27 plants	Ovule, seed	Mundt and Hinkle 1976
Brevundimonas	Potato	Seedlings	Garbeva et al. 2001
Burkholderia cepacia	Banana	Root	Pan et al. 1997
(*Pseudomonas cepacia*)	Cotton	Plant tissues	Chen et al. 1995
Curtobacterium	Canola	Root	Germida et al. 1998
	Citrus	Branch	Araujo et al. 2002
	Citrus	Leaf	Araujo et al. 2001
	Clover	Root	Sturz et al. 1998
	Corn	Root	McInroy and Kloepper 1995b
	Corn	Stem	Zinniel et al. 2002

Bacterial Endophyte	Plant	Organ	Reference
Curtobacterium	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Root	McInroy and Kloepper 1995
	Elm	Stem, root	Mocali et al. 2003
	Grapevine	Xylem	Bell et al. 1995
	Potato	Tuber	Sturz et al. 1999
	Potato	Tuber	Sturz et al. 1998
	Red Clover	Root	Sturz and Christie 1998
	Red Clover	Root, nodule	Sturz et al. 1997
	Rice	Root	Germida and Siciliano 2001
	Sorghum	Stem	Zinniel et al. 2002
	Wheat	Root	Germida and Siciliano 2001
	Yam	Tuber	Mantell 1998
	200 plant species	Leaf	Dunleavy 1989
Enterobacter	Citrus	Leaf	Araujo et al. 2001
	Citrus	Branch	Araujo et al. 2002
	Clover	Root	Sturz et al. 1998
	Corn	Stem	Zinniel et al. 2002
	Corn	Root	Hinton and Bacon 1995
	Corn	Stem	Fisher et al. 1992
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Root	McInroy and Kloepper 1995a
	Elm	Stem, root	Mocali et al. 2003
	Grapevine	Xylem	Bell et al. 1995
	Lemon	Root	Gardner et al. 1982
	Potato	Tuber	Sturz et al. 1998
	Potato	Seedlings	Garbeva et al. 2001
	Red Clover	Plant tissues	Sturz et al. 1997
	Red Clover	Root	Sturz and Christie 1998
	Rice	Root	Yang et al. 1999
	Rice	Seedlings	Mukhopadhyay et al. 1996
	Sorghum	Stem	Zinniel et al. 2002
	Spinach	Root	Tsuda et al. 2001
	Wheat	Root	Germida and Siciliano 2001
	Yam	Tuber	Omoregie et al. 1999
	Yam	Tuber	Mantell 1998
	27 plants	Ovule, seed	Mundt and Hinkle 1976
Klebsiella	Clover	Root	Sturz et al. 1998
	Corn	Root	Palus et al. 1996
	Corn	Root	Riggs et al. 2001
	Corn	Stem	Zinniel et al. 2002
	Corn	Root	Chelis and Triplett 2000
	Corn	Stem	Fisher et al. 1992
	Cotton	Root	McInroy and Kloepper 1995
	Grapevine	Xylem	Bell et al. 1995

Bacterial Endophyte	Plant	Organ	Reference
Klebsiella	Lemon	Root	Gardner et al. 1982
	Potato	Tuber	Sturz et al. 1998
	Rice	Stem, seed	Elbeltagy et al. 2000
	Rice	Root	Englehard et al. 2000
	Sorghum	Stem	Zinniel et al. 2002
Microbacterium	Corn	Root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Potato	Seedlings	Garbeva et al. 2001
	Sorghum	Stem	Zinniel et al. 2002
Aureobacterium	Cotton	Plant tissues	Chen et al. 1995
synonym Microbacterium	Trufgrass	Seed, root	Sundaram et al. 1988
Mycobacterium	Scots pine	Bud	Mattila 2001
Pantoea	Citrus	Leaf	Araujo et al. 2001
	Citrus	Branch	Araujo et al. 2002
	Clover	Root	Sturz et al. 1998
	Corn	Root	Riggs et al. 2001
	Cotton	Root	McInroy and Kloepper 1995
	Grapevine	Xylem	Bell et al. 1995
	Oilseed rape	Seedlings	Graner et al. 2003
	Pea	Stem	Elvira-Recuenco & van Vuurde 2000
	Potato	Tuber	Sturz et al. 1999
	Potato	Tuber	Sturz et al. 1998
	Potato	Tuber	Sturz and Matheson 1996
	Red Clover	Root, nodule	Sturz et al. 1997
	Rice	Root	Verma et al. 2001
	Rice	Stem, seed	Elbeltagy et al. 2000
	Wheat	Root	Ruppel et al. 1992
	Yam	Tuber	Omoregie et al. 1999
	Nonlegumin-ous plants	Apoplast	Hecht-Buchholz 1998
Pseudomonas	Alfalfa	Root	Gagne et al. 1987
	Canola	Root	Misko and Germida 2002
	Carrots	Tuber	Surette et al. 2003
	Cherry	Plant tissues	Cameron 1970
	Clover	Root	Sturz et al. 1998
	Corn	Root	McInroy and Kloepper 1995
	Corn	Stem	Zinniel et al. 2002
	Corn	Stem	Fisher et al. 1992
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Root	McInroy and Kloepper 1995
	Cotton	Seedlings	Zhao and Ma 1999
	Elm	Stem, root	Mocali et al. 2003
	Grapevine	Xylem	Bell et al. 1995
	Lemon	Root	Gardner et al. 1982
	Live oak	Plant tissues	Brooks et al. 1994

Bacterial Endophyte	Plant	Organ	Reference
Pseudomonas	Oilseed rape	Seedlings	Graner et al. 2003
	Onion	Root	Barka et al. 2002
	Pea	Stem	Elvira-Recuenco & van Vuurde 2000
	Pear	Stem,root	Whitesides and Spotts 1991
	Potato	Plant tissues	De Boer and Copeman 1974
	Potato	Seedlings	Garbeva et al. 2001
	Potato	Tuber	Sturz et al. 1999
	Potato	Tuber	Sturz et al. 1998
	Red Clover	Root	Sturz and Christie 1998
	Red Clover	Root, nodule	Sturz et al. 1997
	Rice	Root	Yang et al. 1999
	Rice	Stem, root	Adhikari et al. 2001
	Scots pine	Buds	Mattila 2001
	Sorghum	Stem	Zinniel et al. 2002
	Sugar beet	Root	Jacobs et al. 1985
	Wheat	Root	Germida and Siciliano 2001
	Yam	Tuber	Mantell 1998
	Vegetables	Plant tissues	Meneley and Stanghellini 1972
	27 plants	Ovule, seed	Mundt and Hinkle 1976
Rhizobium	Carrots	Tuber	Surette et al. 2003
	Clover	Root	Philipson and Blair 1957
	Corn	Root	McInroy and Kloepper 1995
	Corn	Stem	Zinniel et al. 2002
	Cotton	Root	McInroy and Kloepper 1995
	Potato	Tuber	Sturz et al. 1999
	Potato	Seedlings	Garbeva et al. 2001
	Red Clover	Root, nodule	Sturz et al. 1997
	Red Clover	Root	Struz and Christie 1998
	Rice	Root	Yang et al. 1999
	Sorghum	Stem	Zinniel et al. 2002
	Wheat	Root	Germida and Siciliano 2001
	Nonlegumin-ous plants	Apoplast	Hecht-Buchholz 1998
Sphingomonas	Clover	Root	Sturz et al. 1998
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Root	McInroy and Kloepper 1995
	Elm	Stem, root	Mocali et al. 2001
	Potato	Tuber	Sturz et al. 1999
	Potato	Tuber	Sturz et al. 1998
	Red clover	Root	Sturz and Christie 1998
	Rice	Plant tissues	Elbeltagy et al. 2000
	Rice	Root	Englehard et al. 2000
	Rice	Stem, root	Adhikari et al. 2001

Bacterial Endophyte	Plant	Organ	Reference
Staphylococcus	Canola	Root	Germida et al. 1998
	Carrots	Tuber	Surette et al. 2003
	Corn	Root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Root	McInroy and Kloepper 1995
	Elm	Stem, root	Mocali et al. 2003
	Grapevine	Xylem	Bell et al. 1995
	Rice	Root	Yang et al. 1999
Stenotrophomonas	Corn	Root	McInroy and Kloepper 1995
	Elm	Stem, root	Mocali et al. 2003
	Potato	Plant tissues	Garbeva et al. 2001
Xanthomonas	Citrus	Branch	Araujo et al. 2002
	Clover	Root	Sturz et al. 1998
	Corn	Root	McInroy and Kloepper 1995
	Corn	Stem	Zinniel et al. 2002
	Cotton	Seedlings	Zhao and Ma 1999
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Root	Misaghi and Donndellinger 1990
	Grapevine	Xylem	Bell et al. 1995
	Mulberry	Shoot	Sato et al. 2000
	Pinto beans	Stem	Thomas and Graham 1948
	Potato	Plant tissues	De Boer and Copeman 1974
	Potato	Tuber	Sturz et al. 1998
	Potato	Tuber	Sturz et al. 1999
	Red Clover	Plant tissues	Struz et al. 1997
	Red Clover	Root	Sturz and Christie 1998
	Rice	Root	Germida and Siciliano 2001
	Rice	Root	Yang et al. 1999
	Sorghum	Stem	Zinniel et al. 2002
	Sugar beet	Root	Jacobs et al. 1985
	Wheat	Root	Germida and Siciliano 2001
	Yam	Tuber	Mantell 1998
	Vegetables	Plant tissues	Meneley and Stanghellini 1972
	27 plants	Ovule, seed	Mundt and Hinkle 1976

Appendix 9. Bacterial endophytes documented in other studies but not documented in this study of the crown tissue from Midlawn and Tifgreen cultivars of bermudagrass.

Bacterial Endophyte	Plant	Organ	Reference
Acetobacter	Pineapple	Plant tissues	Tapia et al. 2000
	Sugarcane	Stem	Dong et al. 1994
Acetobacterium	Sea grass	Cortex	Kusel et al. 1999
Achromobacter	Citrus	Xylem	Gardner et al. 1982
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Acinetobacter	Citrus	Xylem	Gardner et al. 1982
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Stem	McInroy and Kloepper 1995
	Potato	Tuber	Sturz et al. 1998
	Nonleguminous plants	Apoplast	Hecht-Buchholz 1998
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Actinomycetes	Citrus	Xylem	Gardner et al. 1982
Aerococcus	Cotton	Plant tissues	Chen et al. 1995
Aeromonas	Rice	Root	Yang et al. 1999
Agrobacterium	Carrot	Plant tissues	Surette et al. 2003
	Clover	Root	Sturz et al. 1998
	Cotton	Plant tissues	Chen et al. 1995
	Healthy rose	Plant tissues	Marti et al. 1999
	Potato	Plant tissues	De Boer and Copeman 1974
	Potato	Tuber	Sturz et al. 1998
	Red clover	Root	Struz and Christie 1998
	Rice	Root	Germida and Siciliano 2001
Alcaligenes	Citrus	Branch	Araujo et al. 2002
	Citrus	Leaf	Araujo et al. 2001
	Cotton	Root	McInroy and Kloepper 1995
	Oliseed rape	Seedling	Graner et al. 2003
	Potato	Tuber	Sturz et al. 1998
	Red clover	Root	Sturz and Christie 1998
	Rice	Root	Yang et al. 1999
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Arthrobacter	Canola	Root	Germida et al. 1998
	Citrus	Xylem	Gardner et al. 1982
	Clover	Root	Sturz et al. 1998
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Stem	McInroy and Kloepper 1995
	Potato	Tuber	Sturz et al. 1998
	Potato	Tuber	Sturz et al. 1999
	Rice	Root	Germida and Siciliano 2001
	Red clover	Root	Sturz and Christie 1998

Bacterial Endophyte	Plant	Organ	Reference
Azoarcus	Rice	Root	Englehard et al. 2000
	Nonleguminous plants	Apoplast	Hecht-Buchholz 1998
Azorhizobium	Rice	Root	Englehard et al. 2000
Azospirillum	Rice	Plant tissues	Elbeltagy et al. 2000
	Rice	Root	Englehard et al. 2000
	Nonleguminous plants	Apoplast	Hecht-Buchholz 1998
Bortedella	Clover	Root	Sturz et al. 1998
	Red clover	Nodule	Sturz et al. 1997
Brandyrhizobium	Corn, Sorghum	Aerial tissues	Zinniel et al. 2002
Brevibacterium	Cotton	Plant tissues	Chen et al. 1995
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Burkholderia	Banana	Plant tissues	Pan et al. 1997
	Citrus	Branch	Araujo et al. 2002
	Citrus	Leaf	Araujo et al. 2001
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Stem, root	McInroy and Kloepper 1995
	Lupine	Shoot, root	Baldandreau et al. 2001
	Rice	Root	Englehard et al. 2000
	Sugarcane	Plant tissues	Boddey et al. 2003
	Wheat	Shoot, root	Baldandreau et al. 2001
Capnocytophaga	Clover	Root	Sturz et al. 1998
	Red clover	Root	Sturz and Christie 1998
Cedecea	Cotton	Plant tissues	Chen et al. 1995
Cellulomonas	Clover	Root	Sturz et al. 1998
	Corn, Sorghum	Aerial tissues	Zinniel et al. 2002
	Cotton	Stem, root	McInroy and Kloepper 1995
	Potato	Tuber	Sturz et al. 1999
	Potato	Tuber	Sturz et al. 1998
Chryseomonas	Cotton	Plant tissues	Chen et al. 1995
	Rice	Root	Yang et al. 1999
Citrobacter	Citrus	Xylem	Gardner et al. 1982
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
Clavibacter	Corn	Stem, root	McInroy and Kloepper 1995
	Corn, Sorghum	Aerial tissues	Zinniel et al. 2002
	Grapevine	Xylem	Bell et al. 1995
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Stem, root	McInroy and Kloepper 1995
	Cotton	Whole plant	Misaghi and Donndelinger 1990
	Potato	Tuber	Sturz et al. 1999
	Potato	Tuber	Sturz et al. 1998
	Rice	Root	Germida and Siciliano 2001

Bacterial Endophyte	Plant	Organ	Reference
Clostridium carbonei	Pinto beans	Plant tissues	Thomas and Graham 1952
Comamonas	Clover	Root	Sturz et al. 1998
	Cotton	Root	McInroy and Kloepper 1995
	Grapevine	Xylem	Bell et al. 1995
	Oilseed rape	Seedling	Graner et al. 2003
	Potato	Tuber	Sturz et al. 1998
	Red clover	Root	Sturz et al. 1997
Corynebacterium	Citrus	Xylem	Gardner et al. 1982
	Corn, Sorghum	Aerial tissues	Zinniel et al. 2002
	Cotton	Plant tissues	Chen et al. 1995
	Pinto Beans	Stem	Thomas and Graham 1952
	Rice	Plant tissues	Elbeltagy et al. 2000
	Sugar beet	Root	Jacobs et al. 1985
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Curtobacter	Canola	Root	Germida et al. 1998
Cytophaga	Rice	Root	Germida and Siciliano 2001
	27 plant species	Ovule,seed	Mundt and Hinkle 1976
Cytophagales	Rice	Plant tissues	Elbeltagy et al. 2000
Deleya	Clover	Root	Sturz et al. 1998
	Potato	Tuber	Sturz et al. 1998
Desulfovibrio	Sea grass	Cortex	Kusel et al. 1999
Erwinia	Aspen	Wood	Knutson 1973
	Corn, Sorghum	Aerial tissues	Zinniel et al. 2002
	Cotton	Plant tissues	Misaghi and Donndelinger 1990
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Stem, root	McInroy and Kloepper 1995
	Cotton	Seedlings	Zhao and Ma 1999
	Oilseed rape	Seedlings	Graner et al. 2003
	Potato	Tuber	Sturz et al. 1998
	Red clover	Root	Sturz and Christie 1998
	Rice	Root	Germida and Siciliano 2001
	Sugar beet	Root	Jacobs et al. 1985
	Vegetables	Plant tissues	Meneley and Stanghellini 1972
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Esherichia	Corn	Stem, root	McInroy and Kloepper 1995
	Corn, Sorghum	Aerial tissues	Zinniel et al. 2002
	Cotton	Stem, root	McInroy and Kloepper 1995
	Red clover	Stem	Sturz et al. 1997
Flavimonas	Corn	Root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
Flavobacterium	Canola	Root	Germida et al. 1998
	Citrus	Xylem	Gardner et al. 1982
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Root	McInroy and Kloepper 1995

Bacterial Endophyte	Plant	Organ	Reference
Flavobacterium	Potato	Plant tissues	De Boer and Copeman 1974
	Potato	Tuber	Sturz et al. 1998
	Potato	Stem, root	Garbeva et al. 2001
	Red clover	Root	Sturz and Christie 1998
	Rice	Plant tissues	Elbeltagy et al. 2000
	Rice	Root	Germida and Siciliano 2001
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Gallionella	Rice	Root	Englehard et al. 2000
Gluconacetobacter	Sugarcane	Plant tissues	Boddey et al. 2003
Herbaspirillum	Rice	Plant tissues	Elbeltagy et al. 2000
	Rice	Root	Englehard et al. 2000
	Sugarcane	Plant tissues	Boddey et al. 2003
	Nonleguminous plants	Apoplast	Hecht-Buchholz 1998
Hydrogenophaga	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Stem, root	McInroy and Kloepper 1995
Kingella	Potato	Tuber	Sturz et al. 1999
	Red clover	Root	Sturz and Christie 1998
Kluyvera	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Root	McInroy and Kloepper 1995
Kurtia	Oilseed rape	Seedlings	Graner et al. 2003
Lactobacillus	Sugar beet	Root	Jacobs et al. 1985
Leuconostoc	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Methylobacterium	Citrus	Branch	Araujo et al. 2002
	Citrus	Leaf	Araujo et al. 2001
	Clover	Root	Struz et al. 1998
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Stem, root	McInroy and Kloepper 1995
	Red clover	Root	Sturz et al. 1997
	Scots pine	Plant tissues	Mattila 2001
Microbispora	Cereal plants	Plant tissues	Coombs et al. 2003
	Corn	Leaf	de Araujo et al. 2000
Micrococcus	Canola	Root	Germida et al. 1998
	Clover	Root	Sturz et al. 1998
	Corn, Sorghum	Aerial tissues	Zinniel et al. 2002
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Stem, root	McInroy and Kloepper 1995
	Oilseed rape	Seedlings	Graner et al. 2003
	Potato	Plant tissues	De Boer and Copeman 1974
	Potato	Tuber	Sturz et al. 1999
	Potato	Tuber	Sturz et al. 1998

Bacterial Endophyte	Plant	Organ	Reference
Micrococcus	Rice	Root	Germida and Siciliano 2001
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Micromonospora	Cereal plants	Plant tissues	Coombs et al. 2003
Moraxella	Grapevine	Xylem	Bell et al. 1995
Morganella	Cotton	Plant tissues	Chen et al. 1995
	Rice	Seedlings	Mukhopadhyay et al. 1996
Mycobacterium	Scots pine	Bud	Mattila 2001
Nocardia	Citrus	Branch	Araujo et al. 2002
	Potato	Plant tissues	Garbeva et al. 2001
	Rice	Root	Germida and Siciliano 2001
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Nocardioides albus	Cereal plants	Plant tissues	Coombs et al. 2003
Ochrobacterium	Corn	Stem	McInroy and Kloepper 1995
	Cotton	Root	McInroy and Kloepper 1995
	Rice	Root	Englehard et al. 2000
	Rice	Root	Germida and Siciliano 2001
Pasteurella	Potato	Tuber	Sturz et al. 1998
	Red clover	Stem	Sturz et al. 1997
Phtotbaccterium	Potato	Tuber	Sturz et al. 1998
Phyllobacterium	Clover	Root	Sturz et al. 1998
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Red clover	Nodule	Sturz et al. 1997
Promicromonospora	Potato	Tuber	Sturz et al. 1999
Proteus	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Providencia	Citrus	Xylem	Gardner et al. 1982
Psychrobacter	Clover	Root	Sturz et al. 1998
	Potato	Tuber	Sturz et al. 1999
	Potato	Tuber	Sturz et al. 1998
Rahnella	Grapevine	Xylem	Bell et al. 1995
	Oilseed rape	Seedlings	Graner et al. 2003
	Pea	Stem	Elvira-Recuenco & van Vuurde 2000
Rathayibacter	Canola	Root	Germida et al. 1998
	Rice	Root	Germida and Siciliano 2001
Rhodococcus	Cotton	Plant tissues	Chen et al. 1995
	Grapevine	Xylem	Bell et al. 1995
	Rice	Root	Germida and Siciliano 2001
Rhodopseudomonas	Rice	Plant tissues	Elbeltagy et al. 2000
Rothia	Corn, Sorghum	Aerial tissues	Zinniel et al. 2002
Runella zeae sp. nov.	Corn	Stem	Chelis et al. 2002
Salmonella	Cotton	Plant tissues	Chen et al. 1995
	Rice	Root	Germida and Siciliano 2001

Bacterial Endophyte	Plant	Organ	Reference
Serratia	Citrus	Xylem	Gardner et al. 1982
	Clover	Root	Sturz et al. 1998
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Cotton	Stem, root	McInroy and Kloepper 1995
	Potato	Tuber	Sturz et al. 1998
	Rice	Seedlings	Mukhopadhyay et al. 1996
	Yam	Tuber	Mantell 1998
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Shewanella	Potato	Tuber	Sturz et al. 1998
Shigella	Citrus	Xylem	Gardner et al. 1982
Sinorhizobium	Potato	Plant tissues	Garbeva et al. 2001
Sphingobacterium	Potato	Tuber	Sturz et al. 1999
	Rice	Root	Germida and Siciliano 2001
Sphingomonas	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Root	McInroy and Kloepper 1995
	Elm	Stem, root	Mocali et al. 2001
	Potato	Tuber	Sturz et al. 1999
	Red clover	Root	Sturz and Christie 1998
	Rice	Plant tissues	Elbeltagy et al. 2000
Streptococcus	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Streptomyces	Cereal plants	Plant tissues	Coombs et al. 2003
	Citrus	Branch	Araujo et al. 2002
	Corn	Leaf	de Araujo et al. 2000
	Laurel	Plant tissues	Nishimura et al. 2002
	Ryegrass	Plant tissues	Gurney and Mantle 1993
	Kennedia nigriscans	Plant tissues	Castillo-Uvidelio et al. 2002
	27 plant species	Ovule, seed	Mundt and Hinkle 1976
Streptosporangium	Corn	Leaf	de Araujo et al. 2000
Variovorax	Clover	Root	Sturz et al. 1998
	Corn	Stem, root	McInroy and Kloepper 1995
	Cotton	Root	McInroy and Kloepper 1995
	Potato	Tuber	Sturz et al. 1999
	Rice	Root	Germida and Siciliano 2001
Vibrio	Citrus	Xylem	Gardner et al. 1982
	Corn	Stem	Fisher et al. 1992
	Potato	Tuber	Sturz et al. 1998
Yersinia	Citrus	Xylem	Gardner et al. 1982
	Corn	Stem	McInroy and Kloepper 1995
	Cotton	Stem, root	McInroy and Kloepper 1995
	Cotton	Plant tissues	Chen et al. 1995
	Rice	Seedlings	Mukhopadhyay et al. 1996

Appendix 10. Plant bacterial endophytes with documented antagonism towards pathogens.

Bacterial Endophyte	Isolated From	Antagonism Property	Experiment Type	Plant	Pathogen	Reference
Acidovorax delafieldii	Oilseed rape	Antagonism	*In vitro*		*Verticillium longisporum*	Graner et al. 2003
Acinetobacter	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Aerococcus	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Agrobacterium	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Agrobacterium rubi	Oilseed rape	Antagonism	*In vitro*		*Verticillium longisporum*	Graner et al. 2003
Agrobacterium tumefaciens	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Agrobacterium tumefaciens B	Clover root Potato tuber	Antagonism	*In vitro*		*Rhizoctonia solani*	Sturz et al. 1998
Arthrobacter	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Arthrobacter ilicis	Clover root Potato tuber	Antagonism	*In vitro*		*Rhizoctonia solani*	Sturz et al. 1998
Aureobacterium	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Aureobacterium saperdae INR-6	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Bacillus	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Bacillus brevis	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Bacillus cereus 65	*Sinapis*	Chitinase	*In vitro*		*Rhizoctonia solani*	Pleban et al. 1995
Bacillus cereus 65	*Sinapis*	Chitinase	*In vitro*		*Pythium ultimum*	Pleban et al. 1995

Bacterial Endophyte	Isolated From	Antagonism Property	Experiment Type	Plant	Pathogen	Reference
Bacillus cereus 65	*Sinapis*	Chitinase	*In vitro*		*Sclerotium rolfsii*	Pleban et al. 1995
Bacillus cereus 65	*Sinapis*	Reduced disease	*In planta*	Cotton	*Rhizoctonia solani*	Pleban et al. 1995
Bacillus cereus 65	*Sinapis*	Reduced disease	*In planta*	Bean	*Sclerotium rolfsii*	Pleban et al. 1995
Bacillus cereus 78	Cauliflower	Antagonism	*In vitro*		*Rhizoctonia solani*	Pleban et al. 1995
Bacillus cereus 78	Cauliflower	Reduced disease	*In planta*	Bean	*Sclerotium rolfsii*	Pleban et al. 1995
Bacillus licheniformis	Oilseed rape	Protease	*In vitro*		*Verticillium longisporum*	Graner et al. 2003
Bacillus mojavensis	Corn kernel	Antagonism	*In vitro*		*Fusarium moniliforme*	Bacon and Hinton 2002
Bacillus pumilus 85	Sunflower	Antagonism	*In vitro*		*Rhizoctonia solani*	Pleban et al. 1995
Bacillus pumilus 85	Sunflower	Antagonism	*In vitro*		*Sclerotium rolfsii*	Pleban et al. 1995
Bacillus pumilus 85	Sunflower	Reduced disease	*In planta*	Cotton	*Rhizoctonia solani*	Pleban et al. 1995
Bacillus pumilus JM-1128	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Bacillus pumilus SE34	Endophyte	Induced defense-related ultrastructural modifications	*In planta*	Pea	*Fusarium oxysporum* f. sp. *pisi*	Benhamou et al. 1996a
Bacillus subtilis 72	Onion tissue	Antagonism	*In vitro*		*Rhizoctonia solani*	Pleban et al. 1995
Bacillus subtilis 72	Onion tissue	Antagonism	*In vitro*		*Pythium ultimum*	Pleban et al. 1995
Bacillus subtilis 72	Onion tissue	Reduced disease	*In planta*	Cotton	*Rhizoctonia solani*	Pleban et al. 1995
Bacillus subtilis 72	Onion tissue	Reduced disease	*In planta*	Bean	*Sclerotium rolfsii*	Pleban et al. 1995
Brevibacterium	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Brochothrix	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995

Bacterial Endophyte	Isolated From	Antagonism Property	Experiment Type	Plant	Pathogen	Reference
Burkholderia	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Burkholderia (Pseudomonas) cepacia	Asparagus	Mycelia deformation	*In planta*	Banana	*Fusarium oxysporum* f. sp. *cubense* race 4	Pan et al. 1997
Burkholderia solanacearum JM-869	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Cedeca davisae MK-30	Endophyte	Possible ISR	*In planta*	Tomato	*Meloidogyne incognita* (nematode)	Munif et al. 2001
Cedecea	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Chryseomonas	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Citrobacter	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Clavibacter	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Corynebacterium	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Curtobacteirum flaccumfaciens	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Curtobacterium	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Curtobacterium albidum	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Curtobacterium flaccumfaciens	Clover root Potato tuber	Antagonism	*In vitro*		*Rhizoctonia solani*	Sturz et al. 1998
Curtobacterium luetum	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Cytophaga johnsonae	Oilseed rape	Protease	*In vitro*		*Verticillium longisporum*	Graner et al. 2003

Bacterial Endophyte	Isolated From	Antagonism Property	Experiment Type	Plant	Pathogen	Reference
Enterobacter	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Enterobacter (Pantoea) agglomerans	Clover root Potato tuber	Antagonism	*In vitro*		*Rhizoctonia solani*	Sturz et al. 1998
Enterobacter cloacae	Spinach root	Antagonism	*In planta*	Spinach	*Fusarium oxysporum* f. sp. *spinaciae*	Tsuda et al. 2001
Enterobacter sp. MK-42	Endophyte	Possible ISR	*In planta*	Tomato	*Meloidogyne incognita* (nematode)	Munif et al. 2001
Erwinia	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Flavimonas	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Flavobacterium	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Hydrogenophaga	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Klebsiella pneumonia	Clover root Potato tuber	Antagonism	*In vitro*		*Rhizoctonia solani*	Sturz et al. 1998
Methylobacterium	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Microbacterium	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Micrococcus	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Micrococcus varians	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Morganella	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Nocardioides albus	Cereal	Antagonism	*In planta*	Wheat	*Gaeumannomyces graminis* var. *tritici*	Coombs et al. 2003

Bacterial Endophyte	Isolated From	Antagonism Property	Experiment Type	Plant	Pathogen	Reference
Paenibacillus polymyxa	Oilseed rape	Protease	*In vitro*		*Verticillium longisporum*	Graner et al. 2003
Pantoea agglomerans	Potato tuber	Antagonism	*In vitro*		*Erwinia cartovor*a var. *atroseptica*	Struz and Matheson 1996
Pantoea agglomerans	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Pantoea agglomerans MK-29	Endophyte	Possible ISR	*In planta*	Tomato	*Meloidogyne incognita* (nematode)	Munif et al. 2001
Phyllobacterium	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Phyllobacterium rubiacearum JM-1137	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Pseudomonas	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Pseudomonas cichorii	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Pseudomonas cichorii	Potato tuber	Antagonism	*In vitro*		*Fusarium avenaceum, oxysporum, sambucinum*	Sturz et al. 1999
Pseudomonas corrugata	Clover root Potato tuber	Antagonism	*In vitro*		*Fusarium oxysporum* f. sp. *radicis-lycopersici*	Sturz et al. 1998
Pseudomonas corrugata	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Pseudomonas corrugata	Potato tuber	Antagonism	*In vitro*		*Fusarium avenaceum, oxysporum, sambucinum*	Sturz et al. 1999
Pseudomonas fluorescens	Oilseed rape	Antagonism	*In vitro*		*Verticillium longisporum*	Graner et al. 2003
Pseudomonas fluorescens S3	Endophyte	Antagonism	*In planta*	Rice	*Achlya klebsiana*	Adhikari et al. 2001
Pseudomonas fluorescens S3	Endophyte	Antagonism	*In planta*	Rice	*Pythium spinosum*	Adhikari et al. 2001
Pseudomonas putida	Oilseed rape	Protease	*In vitro*		*Verticillium longisporum*	Graner et al. 2003

Bacterial Endophyte	Isolated From	Antagonism Property	Experiment Type	Plant	Pathogen	Reference
Pseudomonas putida 1-15	Live Oak	Antagonism	*In planta*	Live oak	*Ceratocystis fagacearum*	Brooks et al. 1994
Pseudomonas putida 5-48	Live Oak	Antagonism	*In planta*	Live oak	*Ceratocystis fagacearum*	Brooks et al. 1994
Pseudomonas putida 89B-61	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Pseudomonas putida CC-186	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Pseudomonas putida MT-19	Endophyte	Possible ISR	*In planta*	Tomato	*Meloidogyne incognita* (nematode)	Munif et al. 2001
Pseudomonas talaasii	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Pseudomonas tolaasi S20	Endophyte	Antagonism	*In planta*	Rice	*Achlya klebsiana*	Adhikari et al. 2001
Pseudomonas tolaasi S20	Endophyte	Antagonism	*In planta*	Rice	*Pythium spinosum*	Adhikari et al. 2001
Pseudomonas tolaasii	Potato tuber	Antagonism	*In vitro*		*Fusarium avenaceum, oxysporum, sambucinum*	Sturz et al. 1999
Pseudomonas veronii S21	Endophyte	Antagonism	*In planta*	Rice	*Achlya klebsiana*	Adhikari et al. 2001
Pseudomonas veronii S21	Endophyte	Antagonism	*In planta*	Rice	*Pythium spinosum*	Adhikari et al. 2001
Rahnella aquatilis	Oilseed rape	Antagonism	*In vitro*		*Verticillium longisporum*	Graner et al. 2003
Rhizobium meliloti	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1, A2	Sturz et al. 1999
Rhodococcus	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Salmonella	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Serratia	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995

Bacterial Endophyte	Isolated From	Antagonism Property	Experiment Type	Plant	Pathogen	Reference
Serratia plymuthica	Endophyte	Induced resistance	*In planta*	Cucum-ber	*Pythium ultimum*	Benhamou et al. 2000
Sphingomonas paucimobilis	Potato tuber	Antagonism	*In vitro*		*Phytophthora infestans* A1&2	Sturz et al. 1999
Sphingomonas trueperi S12	Endophyte	Antagonism	*In planta*	Rice	*Achlya klebsiana*	Adhikari et al. 2001
Sphingomonas trueperi S12	Endophyte	Antagonism	*In planta*	Rice	*Pythium spinosum*	Adhikari et al. 2001
Staphylococcus	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Streptomyces bikiniensis	Cereal plants	Antagonism	*In planta*	Wheat	*Gaeumannomyces graminis* var. *tritici*	Coombs et al. 2003
Streptomyces caviscabies	Cereal plants	Antagonism	*In planta*	Wheat	*Gaeumannomyces graminis* var. *tritici*	Coombs et al. 2003
Streptomyces galilaeus	Cereal plants	Antagonism	*In planta*	Wheat	*Gaeumannomyces graminis* var. *tritici*	Coombs et al. 2003
Streptomyces NRRL3052	*Kennedia nigriscans*	Munumbicins A-D antibiotics	*In ivtro*		Did not state.	Castillo et al. 2002
Streptomyces sp.	Perennial ryegrass	1-N-methylalbono-ursin	*In vitro*		Did not state.	Gurney and Mantel 1993
Streptomyces sp. AOK-30	Mountain Laural	Antimicrobial	*In planta*	Laurel	*Pestalotiopsis sydowiana*	Nishimura et al. 2002
Streptomyces argenteolus	Cereal	Antagonism	*In planta*	Wheat	*Gaeumannomyces graminis* var. *tritici*	Coombs et al. 2003
Xanthomonas	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995
Xanthomonas campestris	Clover root Potato tuber	Antagonism	*In vitro*		*Rhizoctonia solani*	Sturz et al. 1998
Xanthomonas oryzae	Potato tuber	Antagonism	*In vitro*		*Fusarium avenaceum, oxysporum*	Sturz et al. 1999
Yersinia	Cotton	Antagonism	*In planta*	Cotton	*Fusarium oxysporum* f. sp. *vasinfectum*	Chen et al. 1995

BIBLIOGRAPHY

Abraham, W. R., C. Strompl, et al. (1999). "Phylogeny and polyphasic taxonomy of *Caulobacter* species. Proposal of *Maricaulis* gen. nov. with *Maricaulis maris* (Ponidexter) comb. nov. as the type species, and emended description of the genera *Brevundimonas* and *Caulobacter*." Int. J. Syst. Bacteriol. 49(3): 1053-1073.

Adhikari, T. B., C. M. Joseph, et al. (2001). "Evaluation of bacteria isolated from rice for plant growth promotion and biological control of seedling disease of rice." Can. J. Microbiol. 47: 916-924.

Araújo, W. L., W. Maccheroni Jr., et al. (2001). "Variability and interactions between endophytic bacteria and fungi isolated from leaf tissues of citrus rootstocks." Can. J. Microbiol. 47: 229-236.

Araújo, W. L., J. Marcon, et al. (2002). "Diversity of endophytic bacterial populations and their interaction with *Xylella fastidiosa* in citrus plants." Appl. Environ. Microbiol. 68: 4906-4914.

Ash, C., J. A. E. Farrow, et al. (1991). "Phylogenetic heterogeneity of the genus *Bacillus* revealed by comparative analysis of small subunit ribosomal RNA sequences." Lett. Appl. Microbiol. 13: 202-206.

Bacon, C. W. and D. M. Hinton (2002). "Endophytic and biological control potential of *Bacillus mojavensis* and related species." Biological Control 23(3): 274-284.

Balandreau, J., V. Viallard, et al. (2001). "*Burkholderia cepacia* genomovar III is a common plant-associated bacterium." Appl. Environ. Microbiol. 67: 982-985.

Barka, E. A., S. Gognies, et al. (2002). "Inhibitory effect of endophyte bacteria on *Botrytis cinerea* and its influence to promote the grapevine growth." Biol. Control 24: 135-142.

Bell, C. R., G. A. Dickie, et al. (1995). "Endophytic bacteria in grapevine." Can. J. Microbiol. 41: 46-53.

Benhamou, N., R. R. Belanger, et al. (1996). "Induction of differential host responses by *Pseudomonas fluorescens* in Ri T-DNA-transformed pea roots after challenge with *Fusarium oxysporum* f. sp. *pisi* and *Pythium ultimum*." Phytopathology 86: 1174-1185.

Benhamou, N., S. Gagné, et al. (2000). "Bacterial-mediated induced resistance in cucumber: beneficial effect of the endophytic bacterium *Serratia plymuthica* on the protection against infection by *Pythium ultimum*." Phytopathology 90(1): 45-56.

Boddey, R. M., S. Urquiaga, et al. (2003). "Endophytic nitrogen fixation in sugarcane: present knowledge and future applications." Plant and Soil 252: 139-149.

Bonheyo, G. T., B. W. Fouke, et al. (2004). "Microbial 16S rRNA diversity within travertine depositional facies from 73 degrees to 25 degrees C at Angel Terrace, Mammoth Hot Springs, Yellowstone National Park, USA." Unpublished.

Boye, K. and D. S. Hansen (1999). "Sequencing of 16S genes from *Klebsiella*." Unpublished.
Brooks, D. S., C. F. Gonzalez, et al. (1994). "Evaluation of endophytic bacteria as potential biological control agents for oak wilt." Biological Control 4: 373-381.
Cameron, H. R. (1970). "*Pseudomonas* content of cherry trees." Phytopathology 60: 1343-1346.
Castillo, U. F., G. A. Strobel, et al. (2002). "Munumbicins, wide-spectrum antibiotics produced by *Streptomyces* NRRL 30462, endophytic on *Kennedia nigriscans*." Microbiology 148: 2675-2685.
Chelius, M. K. and E. W. Triplett (2000). "Immunolocalization of dinitrogenase reductase produced by *Klebsiella pneumoniae* in association with *Zea mays* L." Appl. Environ. Microbiol. 66: 783-787.
Chen, C., E. M. Bauske, et al. (1995). "Biological control of Fusiarum wilt on cotton by use of endophytic bacteria." Biological Control 5: 83-91.
Chen, Y.-F., J.-H. Guo, et al. (2003). "*Curtobacterium flaccumfaciens* pv. *beticola* pv. nov., a new pathovar of pathogen on sugar beet." Unpublished.
Coombs, J. T., P. P. Michelsen, et al. (2003). "Evaluation of endophytic actinobacteria as antagonists of *Gaeumannomyces graminis* var. *tritici* in wheat." Biol. Control in press.
Coutinho, T. A., O. Preisig, et al. (2001). "Bacterial blight and die-back of *Eucalyptus* species, hybrids and clones in South Africa." Unpublished.
de Araujo, J. M., A. C. da Silva, et al. (2000). "Isolation of endophytic actinomycetes from roots and leaves of maize (*Zea mays* L.)." Brazilian Archives of Biology and Technology 43(4): 447-451.
De Boer, S. H. and R. J. Copeman (1974). "Endophytic bacterial flora in *Solanum tuberosum* and its significance in bacterial ring rot diagnosis." Canadian Journal of Plant Science 54: 115-122.
Dong, Z., M. J. Canny, et al. (1994). "A nitrogen-fixing endophyte of sugarcane stems: a new role for the apoplast." Plant Physiol. 105: 1139-1147.
Drancourt, M., C. Bollet, et al. (2001). "Phylogenetic analyses of *Klebsiella* species delineate *Klebsiella* and *Raoultella* gen. nov., with description of *Raoultella ornithinolytica* comb. nov., *Raoultella terrigena* comb. nov. and *Raoultella planticola* comb. nov." Int. J. Syst. Evol. Microbiol. 51(3): 925-932.
Dunleavy, J. M. (1989). "*Curtobacterium plantarum* sp. nov. is ubiquitous in plant leaves and is sseed transmitted in soybean and corn." Int. J. Syst. Bacteriol. 39(3): 240-249.
Elbeltagy, A., K. Nishioka, et al. (2000). "Isolation and characterization of endophytic bacteria from wild and traditionally cultivated rice varieties." Soil Sci. Plant Nutr. 46: 617-629.
Elvira-Recuenco, M. and J. W. L. van Vuurde (2000). "Natural incidence of endophytic bacteria in pea cultivars under field conditions." Can. J. Microbiol. 46: 1036-1041.
Engelhard, M., T. Hurek, et al. (2000). "Preferential occurrence of diazotrophic endophytes, *Azoarcus* spp., in wild rice species and land races of *Oryza sativa* in comparison with modern races." Environ. Microbiol. 2: 131-141.

Eppard, M., W. E. Krumbein, et al. (1996). "Morphological, physiological, and molecular characterization of actinomycetes isolated from dry soil, rocks and monument surfaces." Arch. Microbiol. 166(1): 12-22.

Evtushenko, L. I., L. V. Dorofeeva, et al. (2000). Diversity and phylogeny of plant-nematode *Microbacteriaceae*., National Center for Biotechnology Information. 2004.

Fisher, P. J., O. Petrini, et al. (1992). "The distribution of some fungal and bacterial endophytes in maize (*Zea mays* L.)." New Phytol. 122: 299-305.

Fritz, I. (1999). Das Bakterioplankton im Westlichen Mittelmeer. Analyse der tasonomischen Struktur freilebender und partikelgebundener bakterieller Lebensgemeinschaften mit mikrobiologischen und molekularbiologischen Methoden. Department of Microbiology. Graunschweig, Germany, Technische Universitate Carolo-Wilhelmina Braunschweig.

Fukuda, K., S. Nagata, et al. (2001). "Isolation and characterization of dibenzofuran-degrading bacteria." Unpublished.

Gagné, S., C. Richard, et al. (1987). "Xylem-residing bacteria in alfalfa roots." Can. J. Microbiol. 33: 996-1000.

Garbeva, P., L. S. van Overbeek, et al. (2001). "Analysis of endophytic bacterial communities of potato by plating and denaturing gradient gel electrophoresis (DGGE) of 16S rDNA based PCR fragments." Microb. Ecol. 41: 369-383.

Gardner, J. M., A. W. Feldman, et al. (1982). "Identify and behavior of xylem-residing bacteria in rough lemon roots of Florida citrus trees." Appl. Environ. Microbiol. 43: 1335-1342.

Gee, J. E., B. K. De, et al. (2004). "Use of 16S rRNA gene sequencing for rapid confirmatory identification of *Brucella* isolates." J. Clin. Microbiol. 42(8): 3649-3654.

Germida, J. J. and S. D. Siciliano (2001). "Taxonomic diversity of bacteria associated with the roots of modern, recent and ancient wheat cultivars." Biol. Fertil. Soils.

Germida, J. J., S. D. Siciliano, et al. (1998). "Diversity of root-associated bacteria associated with field-grown canola (*Brassica napus* L.) and wheat (*Triticum aestivum* L.)." FEMS Microbiol. Ecol. 26: 43-50.

Goris, J., W. Dejonghe, et al. (2001). Diversity of jJP4 and pEMT1 transconjugants from A- and B- horizonsoil., National Center for Biotechnology Information.

Graner, G., P. Persson, et al. (2003). "A study on microbial diversity in different cultivars of *Brassica napus* in relation to its wilt pathogen, *Verticillium longisporum*." FEMS Microbiol. Ecol. 224(2): 269-276.

Gurney, K. A. and P. G. Mantle (1993). "Biosynthesis of 1-*N*-methylalbonoursin by an endophytic *Streptomyces* sp. isolated from perennial ryegrass." J. Nat. Prod. 56: 1194-1198.

Hall, T. J., L. R. Schreiber, et al. (1986). "Effects of xylem-colonizing *Bacillus* spp. on Vetricillium wilt in maples." Plant Disease 70: 521-524.

Hecht-Buchholz, C. (1998). "The apoplast-habitat of endophytic dinitrogen-fixing bacteria and their significance for the nitrogen nutrition of nonleguminous plants." Z. Pflanz. Boden. 161: 509-520.

Heuer, H., R. M. Kroppenstedt, et al. (2002). "Effects of T4 lysozyme release from transgenic potato roots on bacterial rhizosphere communities are negligible relative to natural factors." App. Environ. Micorbiol. 68(3): 1325-1335.
Hinton, D. M. and C. W. Bacon (1995). "*Enterobacter cloacae* is an endophytic symbiont of corn." Mycopathologia 129(2): 117-125.
Hoffmann, A., T. Thimm, et al. (1998). "Intergenetic transfer of conjugative and mobilizable plasmids harobored by *Escherichia coli* in the gut of the soil microarthropod *Folsomia candida* (*Collembola*)." Appl. Environ. Microbiol. 64(7): 2652-2659.
Hu, F.-P., J. M. Young, et al. (2001). "Relationships within the *Proteobacteria* of plant pathogenic *Acidovorax* species and subspecies, *Burkholderia* species, and *Herbaspirillum rubrisubalbicans* by sequence analysis of 16S rDNA, numberical analysis and determinative tests." Antonie van Leeuwenhoek 80(3-4): 201-214.
Huber, I. and S. Selenska-Pobell (1994). Characterization of *Rhizobium galegae* by REP-PCR, PFGE and 16S rRNA sequencing. Symbiotic Nitrogen Fixation. P. H. Graham, M. J. Sadowsky and C. P. Vance, Kluwer Academic Publishers: 153-158.
Isenegger, D. A., P. W. J. Taylor, et al. (2003). "Molecular detection of a bacterial contaminant *Bacillus pumilus* in symptomless potato plant tissue cultures." Plant Cell Rep. 21(8): 814-820.
Jacobs, M. J., W. M. Bugbee, et al. (1985). "Enumeration, location, and characterization of endophytic bacteria within sugar beet roots." Can. J. Bot. 63: 1262-1265.
Kim, K. K. and S. Lee (2002). "*Chryesobacterium* sp. nov., CPW406." Unpublished.
Knutson, D. M. (1973). "The bacteria in sapwood, wetwood, and heartwood of trembling aspen (*Populus tremuloides*)." Canadian Journal of Botany 51: 498-500.
Kusel, K., H. C. Pinkard, et al. (1999). "Acetogenic and sulfate-reducing bacteria inhabiting the rhizoplane and deep cortex cells of the sea grass *Halodule wrightii*." Applied and Environmental Microbiology 65: 5117-5123.
La Scola, B., L. Barrassi, et al. (2000). "Isolation of new fastidious alpha proteobacteria and *Afipia felis* from hospital water supplies by direct plating and amoebal co-culture procedures." FEMS Microbiol. Ecol. 34(2): 129-137.
Larran, S., A. Perello, et al. (2002). "Isolation and analysis of endophytic microorganisms in wheat (*Triticum aestivum* L.) leaves." World J. Microbiol. Biotechnol. 18: 683-686.
Lau, S. K., P. C. Woo, et al. (2002). "Catheter-related *Microbacterium* bacteremia identified by 16S rRNA gbene sequencing." J. Clin. Microbiol. 40(7): 2681-2685.
Lee, J. S., Y. K. Shin, et al. (2001). "*Sphingomonas aquatilis* sp. nov., *Sphingomonas koreensis* sp. nov., and *Sphingomonas taejonensis* sp. nov., yellow-pigmented bacteria isolated from natural mineral water." Int. J. Syst. Evol. Microbiol. 51(4): 1491-1498.
Liu, Y., Q. Zhang, et al. (1999). "Population dynamics of endphytic bacteria in symptom-free rice plants." Yingyong Shengtai Xuebao 10(6): 735-738.
Lutman, B. F. and H. E. Wheeler (1948). "*Bacillus megaterium* de Bary from the interior of healthy potato tubers." Journal of the Washington Academy of Sciences 38(10): 336-340.

Macur, R. E., C. R. Jackson, et al. (2004). "Bacterial populations associated with the oxidation and reduction of arsenic in an unsaturated soil." Environ. Sci. Technol. 38(1): 104-111.
Mantell, S. H. (1998). "Microbes intimately associated with tissue and cell cultures of tropical *Dioscorea* yams." Plant Cell Tiss. Org. Cult. 52: 47-52.
Marti, R., J. Cubero, et al. (1999). "Evidence of migration and endophytic presence of *Agrobacterium tumefaciens* in rose plants." Eur. J. Plant Pathol. 105: 39-50.
Matte-Tailliez, O., B. Kerouault, et al. (2003). "Direct submission." Unpublished.
Mattila, A. M. (2001). "Endophytes in the buds of Scots pine (*Pinus sylvestris* L.)." Acta Universitatis Ouluensis A Scientiae Rerum Naturalium 369: 1-55.
McInroy, J. A. and J. W. Kloepper (1995b). "Population dynamics of endophytic bacteria in field-grown sweet corn and cotton." Can. J. Microbiol. 41: 895-901.
McInroy, J. A. and J. W. Kloepper (1995a). "Survey of indigenous bacterial endophytes from cotton and sweet corn." Plant and Soil 173: 337-342.
Meneley, J. C. and M. E. Stanghellini (1972). "Occurrence and significance of soft-rotting bacteria in healthy vegetables." Phytopathology 62: 778.
Mergaert, J., A. Boley, et al. (2001). "Identity and potential functions of heterotrophic bacterial isolates from a continuous-upflow fixed-bed reactor for denitrification of drinking water with bacterial polyester as source of carbon and electron donor." Syst. Appl. Microbiol. 24: 301-303.
Misaghi, I. J. and C. R. Donndelinger (1990). "Endophytic bacteria in symptom-free cotton plants." Phytopathology 80: 808-811.
Misko, A. L. and J. J. Germida (2002). "Taxonomic and functional diversity of pseudomonads isolated from the roots of field-grown canola." FEMS Microbiol. Ecol. 42(3): 399-407.
Mocali, S., E. Bertelli, et al. (2003). "Fluctuation of bacteria isolated from elm tissues during different seasons from different plant organs." Research in Microbiology 154(2): 105-114.
Moore, E. R., A. S. Kruger, et al. (1997). "16S rRNA gene sequence analyses and inter- and intrageneric relationshipis of *Xanthomonas* species and *Stenotrophomonas maltophilia*." FEMS Microbiol. Lett. 151(2): 145-153.
Moore, E. R. B., M. Mau, et al. (1996). "The determination and comparison of the 16S rRNA gene sequences of species of the genus *Pseudomonas* (sensu stricto) and the estimation of their natural intrageneric relationships." Syst. Appl. Microbiol. 19: 478-492.
Mueller, J. G., R. Devereux, et al. (1997). "Phylogenetic and physiologycal comparisons of PAH-degrading bacteria from geographically diverse soils." Antonie Van Leeuwenhoek 71(4): 329-343.
Mukhopadhyay, K., N. K. Garrison, et al. (1996). "Identification and characterization of bacterial endophytes of rice." Mycopathologia 134: 151-159.
Mundt, J. O. and N. F. Hinkle (1976). "Bacteria within ovules and seeds." Applied and Environmental Microbiology 32(5): 694-698.
Munif, A., J. Hallmann, et al. (2001). "Induced systemic resistance of selected endophytic bacteria against *Meloidogyne incognita* on tomato." Mededelingen Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen Universiteit Gent 66: 663-669.

Nishimura, T., A. Meguro, et al. (2002). "An endophytic actinomycete, *Streptomyces* sp,. AOK-30, isolated from mountain laurel and its antifungal activity." Journal of General Plant Pathology 68(4): 390-397.

Normand, P., S. Orso, et al. (1996). "Molecular phylogeny of the genus *Frankia* and related genera and emendation of the family *Frankiaceae*." Int. J. Syst. Bacteriol. 46(1): 1-9.

Omoregie, S. N., H. N. Asemota, et al. (1999). "Occurrence of free-living bacteria in tubers of *Dioscorea* yams." Trop. Agric. (Trinidad) 76: 250-255.

Ovesen, J., T. Coakley, et al. (2002). "Microbial ecology and conduit stream sediment interstitial fluids of the south central Kentucky krast aquifer: Impacts on aquifer development." Unpublished.

Palus, J. A., J. Borneman, et al. (1996). "A diazotrophic bacterial endophyte isolated from stems of *Zea mays* L. and *Zea luxurians* Iltis and Doebley." Plant and Soil 186: 135-142.

Pan, M. J., S. Rademan, et al. (1997). "Ultrastructural studies on the colonization of banana tissue and *Fusarium oxysporum* f. sp. *cubense* Race 4 by the endophytic bacterium *Burkholderia cepacia*." J. Phytopathol. 145: 479-486.

Philipson, M. N. and I. D. Blair (1957). "Bacteria in clover root tissue." Can. J. Microbiol. 3: 125-129.

Pitulle, C., D. F. Bruhn, et al. (2002). "Identification of microorganisms isolated from sludge sediment in storage ponds for spent nuclear fuel." Unpublished.

Pleban, S., L. Chernin, et al. (1997). "Chitinolytic activity of an endophytic strain of *Bacillus sereus*." Letters in Applied Microbiology 25: 284-288.

Pleban, S., F. Ingel, et al. (1995). "Control of *Rhizoctonia solani* and *Sclerotium rolfsii* in the greenhouse using endophytic *Bacillus* spp." European Journal of Plant Pathology 101: 665-672.

Rainey, F. A., N. Weiss, et al. (1994). "Further evidence for the phylogenetic coherence of actinomycetes with group B-peptidoglycan." FEMS Microbiol. Lett. 118: 135-140.

Ramette, A., M. Frapolli, et al. (2001). "Direct submission." Unpublished.

Riggs, P. J., M. K. Chelius, et al. (2001). "Enhanced maize productivity by inoculation with diazotrophic bacteria." Aust. J. Plant Physiol. 28: 829-836.

Rojas, A. M., J. E. Garcia de los Rios, et al. (1999). Phylogenetic analysis of endophytic populations isolated from plants., National Center for Biotechnology Information. 2004.

Roumagnac, P., L. Gagnevin, et al. (2004). "Polyphasic characterization of xanthomonads isolated from onion, garlic and Welsh onion (*Allium* spp.) and their relatedness to different *Xanthomonas* species." Int. J. Syst. Evol. Microbiol. 54(1): 15-24.

Ruppel, S., C. Hecht-Buchholz, et al. (1992). "Settlement of the diazotrophic, phytoeffective bacterial strain *Pantoea agglomerans* on and within winter wheat: An investigation using ELISA and transmission electron microscopy." Plant and Soil 145(2): 261-273.

Sato, M., W. Wei, et al. (2000). "Isolation and characterization of bacteria from colonies exuded from "germ-free" mulberry shoots cultured in vitro." Journal of Sericultural Science of Japan 69(2): 147-152.

Schumann, P., F. A. Rainey, et al. (1999). "Reclassification of *Brevibacterium oxydans* (Chatelain and Second 1966) as *Microbacterium oxydans* comb. nov." Int. J. Syst. Bacteriol. 49(1): 175-177.

Sturz, A. V. and B. R. Christie (1998). "The potential benefits from cultivar specific red clover-potato crop rotations." Ann. Appl. Biol. 133: 365-373.

Sturz, A. V., B. R. Christie, et al. (1998). "Associations of bacterial endophyte populations from red clover and potato crops with potential for beneficial allelopathy." Can. J. Microbiol. 44: 162-167.

Sturz, A. V., B. R. Christie, et al. (1999). "Endophytic bacterial communities in the periderm of potato tubers and their potential to improve resistance to soil-borne plant pathogens." Plant Pathol. 48: 360-369.

Sturz, A. V., B. R. Christie, et al. (1997). "Biodiversity of endophytic bacteria which colonize red clover nodules, roots, stems and foliage and their influence on host growth." Biol. Fertil. Soils 25: 13-19.

Sturz, A. V. and B. G. Matheson (1996). "Populations of endophytic bacteria which influence host-resistance to Erwinia-induced bacterial soft rot in potato tubers." Plant and Soil 184: 265-271.

Sundaram, S., A. Arunakumari, et al. (1988). "Characterization of *Azospirilla* isolated from seeds of turf grass." Can. J. Microbiol. 34: 212-217.

Surette, M. A., A. V. Sturz, et al. (2003). "Bacterial endophytes in processing carrots (*Daucus carota* L. var. *sativus*): Their localization, population density, biodiversity and their effects on plant growth." Plant and Soil 253(2): 381-390.

Suzuki, K., M. Suzuki, et al. (1999). "*Leifsonia* gen. nov., a genus for 2,4-diaminobutyric acid-containing actinomycetes to accomodate '*Corneybacterium aquaticum*' Leifson 1962 and *Clavibacter xyli* subsp. *cynodontis* Davis et al. 1984." J. Gen. Appl. Microbiol. 45: 253-262.

Swiderski, J. (2001). "Direct submission to the National Center for Biotechnology Technology." Unpublished.

Takahashi, T., M. Kaneko, et al. (1996). "Phylogenetic analyses of *Staphylococcus* based on the 16S rDNA sequence and assignment of clinical isolates from animals." Unpublished.

Takeuchi, M. and K. Hatano (1998). "Union of the genera *Microbacterium* Orla-Jensen and *Aureobacterium* Collins et al. in a redefined genus *Micorbacterium*." Int. J. Syst. Bacteriol. 48(3): 739-747.

Takeuchi, M. and A. Yokota (1994). "Phylogenetic analysis of the genus *Microbacterium* based on 16S rRNA gene sequences." FEMS Microbiol. Ecol. 124(1): 11-16.

Tan, G. Y. A., A. C. Ward, et al. (2002). "Genus-specific primers for members of the genus *Amycolatopsis*." Unpublished.

Tapia-Hernandez, A., M. R. Bustillos-Cristales, et al. (2000). "Natural endophytic occurrence of *Acetobacter diazotrophicus* in pineapple plants." Microb. Ecol. 39: 49-55.

Thomas Jr., W. D. and R. W. Graham (1948). "Bacteria in apparently healthy pinto beans." Phytopathology 42: 214.

Trott, S., S. F. Nishino, et al. (2003). "Biodegradation of the nitramine explosive CL-20." Appl. Environ. Microbiol. 69(3): 1871-1974.

Tsuda, K., Y. Kosaka, et al. (2001). "Evaluation of the enodphyte *Enterobacter cloacae* SM10 isolated from spinach roots for biological control against Fusarium wilt of spinach." Journal of General Plant Pathology 67(1): 78-84.
Turenne, C. Y., L. Tschetter, et al. (2001). "Necessity of quality-controlled 16S rRNA gene sequence databases: Identifying nontuberculous *Mycobacterium* species." J. Clin. Microbiol. 39(10): 3637-3648.
Valverde, A., R. Rivas, et al. (2003). "Revival of the species *Rhizobium trifolii* sp. nov., nom. rev. as a different species from *Rhizobium leguminsarum*." Unpublished.
van Berkum, P. and B. D. Eardly (2002). "The aquatic budding bacterium *Blastobacter denitrificans* is a nitrogen-fixing symbiont of *Aeschynomene indica*." Appl. Environ. Microbiol. 68(3): 1132-1136.
Verma, S. C., J. K. Ladha, et al. (2001). "Evaluation of plant growth promoting and colonization ability of endophytic diazotrophs from deep water rice." Journal of Biotechnology 91(2-3): 127-141.
Warwick, S., T. Bowen, et al. (1993). "A phylogenetic analysis of the family *Pseudonocardiaceae* using 16S rRNA sequences." Unpublished.
Whitesides, S. K. and R. A. Spotts (1991). "Frequency, distribution, and characteristics of endophytic Pseudomonas syringae in pear trees." Phytopathology 81: 453-457.
Whitney, A. M. (1997). Direct submission to the National Center for Biotechnology Information. 2004.
Woese, C. R. (1990). "Phylogeny of some gamma purple bacteria based upon 16S rRNA." Unpublished.
Woese, C. R. (1991). "A phylogenetic analysis of the some purple bacteria." Unpublished.
Wolters, J. (1990). Phylogeny of some gamma purple bacteria based upon 16S rRNA., National Center for Biotechnology Information. 2004.
Xu, J., B. C. Millar, et al. (2002). "Direct submission." Unpublished.
Yang, H. L., X. L. Sun, et al. (1999). "Screening, identification and distrubtion of endophytic associative diazotrophs isolated from rice plants." Acta Botanica Sinica 41(9): 927-931.
Yu, W., X. Zhu, et al. (2001). Identification of a strain producing endoglycocermidase. National Center for Biotechnology Information. 2004.
Zhao, F. and H. Ma (1999). "Microecology of cotton seedlings I. Endophyte isolation and measurement of some biochemical characters of normal cotton seedling." Yingyong Shengtai Xuebao 10: 71-73.
Zinniel, D. K., P. Lambrecht, et al. (2002). "Isolation and characterization of endophytic colonizing bacteria from agronomic crops and prairie plants." Appl. Environ. Microbiol. 68: 2198-2208.

VITA

Janice Lynn Hironaka

Candidate for the Degree of

Doctor of Philosophy

Thesis: CULTURABLE BACTERIAL ENDOPHYTES FROM BERMUDAGRASS AND TAQMAN® REAL-TIME PCR TO QUANTIFY *OPHIOSPHAERELLA HERPOTRICHA*

Major Field: Plant Biology

Biographical:

Personal Data: Born in Sacramento, California, USA, on August 6, 1953, to Elaine H. and Jim M. Hironaka.

Education: Bachelor of Sciences from California State University-Sacramento, Sacramento, California, 1995; Master of Science from Oklahoma State University, Stillwater, Oklahoma. Completed the requirements for the Doctorate of Philosophy degree with a major in Plant Sciences at Oklahoma State University, Stillwater, Oklahoma in July, 2005.

Experience: Laboratory Teaching Assistant 1994-1995, Tutor, Athletic Department 1994, "Students with Disabilities Program" 1994, California State University-Sacramento, Sacramento, CA; Volunteer Tutor; Multicultural Student Center 1996-2002, Teaching Assistant, Department of Botany 1997-1999, NASA-AISTEC (National Air and Space Administration-American Indian Science and Technology Education Consortium)1997; Department of Zoology 1998, OPSS (Oklahoma Principals' Science Scholars) 1997, Oklahoma State University, Stillwater, OK 1997; Teaching Assistant, Department of Chemistry, The Pennsylvania State University, University Park, PA 2005.

Professional Memberships: National Association of Biology Teachers, Phycological Society of America.

Name: Janice Lynn Hironaka Date of Degree: July, 2005

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: CULTURABLE BACTERIAL ENDOPHYTES FROM BERMUDAGRASS AND TAQMAN® REAL-TIME PCR TO QUANTIFY *OPHIOSPHAERELLA HERPOTRICHA*

Pages in Study: 228 Candidate for the Degree of Doctor of Philosophy

Major Field: Plant Sciences

Scope and Method of Study: There are several goals of this study. First was to document and putatively identify the culturable bacterial endophytes isolated from surface sterilized crown tissue of Midlawn and Tifgreen cultivars of bermudagrass, secondly, to test these endophytes for antagonistic properties against the Spring Dead Spot (SDS) soilborne fungal pathogen, *Ophiosphaerella herpotricha*, and thirdly, to identify promising candidates for a biological control agent against SDS. Another major goal was to develop a real-time quantitative PCR assay for *O. herpotricha* using TaqMan® chemistry and use this assay to document the spatial distribution of *O. herpotricha* infection in plant and soil samples and document the relationship between resistant and susceptible cultivars of bermudagrass and SDS.

Findings and Conclusions: Seventy-seven Gram-negative and 51 Gram-positive culturable bacterial endophytes, including 31 with *in vitro* antifungal attributes, were readily isolated from the crown tissue of Midlawn and Tifgreen cultivars of bermudagrass, infected with *O. herpotricha* and non-infected. This study is the first, to my knowledge, to document a *Geodermatophilus* sp. and a *Amycolatopsis* sp. as plant endophytes, and of *in vitro* antifungal attributes of a *Chryseobacterium* sp. The abundance and diversity of culturable bacterial endophytes in bermudagrass demonstrate that turfgrasses are good hosts and valuable resources for endophytes with antifungal properties. The cohort of *in vitro* antifungal bacterial endophytes has potential as biological control agents for SDS. A standard-curve real-time quantitative PCR assay with TaqMan® chemistry was developed to identify and quantify the DNA levels of *O. herpotricha* in plant and soil samples. This assay has proven to be quantitative, sensitive, selective, rapid, and easy to perform and may lead to its application to the study of other plant diseases.

ADVISER'S APPROVAL: Michael P. Anderson